MIT Lincoln Laboratory Employee Relocation:

Traffic Impact Study

This report was produced by the Central Transportation Planning Staff for Hanscom Air Force Base

MIT Lincoln Laboratory Employee Relocation: Traffic Impact Study

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Lexington
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Millis
Norwell
Milford
Medway
Weymouth
Walpole
Holbrook
Rockland
Stoughton
Marshfield
Norfolk
Sharon
Hanover
Bellingham
Franklin
Pembroke
Foxborough
Wrenthem
Duxbury
MPO-region boundary
Study area

ABSTRACT

This report documents a study performed for Hanscom Air Force Base to assess the traffic impacts of relocating 532 employees to a new MIT Lincoln Laboratory building at HAFB in 1995. The impacts were assessed through intersection level-of-service analysis. Three scenarios were analyzed: 1990 existing conditions, 1995 No-Build conditions and 1995 Build conditions. The study also identified intersection improvements, where appropriate.

TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

FIGURES

TABLES

1 INTRODUCTION

1.1 DESCRIPTION OF PROJECT

The Massachusetts Institute of Technology (MIT) Lincoln Laboratory, located on the Hanscom Air Force Base (HAFB) in the towns of Bedford, Lexington, and Lincoln, is planning to vacate 235,000 square feet of leased office space located in close proximity to the Air Force Base in the towns of Concord and Lexington.[1] The leased space will be replaced by new on-base construction of 505,000 square feet scheduled for completion in 1995. This 505,000 square feet will accommodate approximately 1288 employees, 756 of which are currently working on base and 532 employees relocated from the vacated leased space. The leased space is located on Hartwell Avenue, Maguire Road and Virginia Road. (For more specific description of the building plan and leased space to be vacated see section 3.1) Therefore, while the relocated employees are currently traveling to the general vicinity of the Air Force Base, the change in work sites for the 532 relocated employees will alter their travel patterns once they are in close proximity to the Air Base.[2] Intersections in the vicinity of HAFB and presently leased space may be impacted by this relocation. In addition, it is assumed that the vacated space will be leased again. The new construction could therefore be viewed as creating new trips to HAFB.

The purpose of this study is to determine the anticipated traffic impacts from the relocation of MIT employees and the "backfill" of presently leased space. The anticipated impacts have been assessed through intersection level-of-service analysis. Thirteen intersections which are likely to be impacted by the relocation have been analyzed. These intersections have been analyzed for three scenarios: 1990 existing conditions, 1995 before the relocation, and 1995 after the relocation. The impacts of the relocation are illustrated through comparison of the 1995 before and after relocation analysis results.

In addition to identifying the impacts of the relocation, existing and future conditions in the study area were evaluated. Suggested traffic improvements, from a variety of sources, are discussed and their potential benefits assessed. These improvements include methods to increase capacity, such as roadway widening, grade separation, signalization, signal

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1. For purposes of convenience and clarity, all MIT Lincoln Laboratory employees being relocated to HAFB, will be referred to as MIT employees in the remainder of this document.

2. A study performed for HAFB and MIT Lincoln Laboratory for a previous plan to relocate 1,182 HAFB and MIT employees was documented in the report entitled: Hanscom Air Force Base Employee Relocation: Traffic Impact Study, by CTPS, Draft Report, October 1990.

retiming, signal rephasing, channelization, and turning-lane additions, and Transportation Demand Management (TDM) techniques. Specific traffic improvement measures which were identified to mitigate the impacts of the employee relocation are also suggested.

1.2 STUDY AREA DEFINITION

The travel demand model developed for the Massachusetts Department of Public Works (MDPW) Route 2 study was used to analyze the effects of the employee relocation. The model covers the towns of Acton, Bedford, Concord, Lexington, Lincoln and a small portion of western Burlington. A map highlighting the extent of the study area is presented in Figure 1-1. The size of this model's study area is sufficiently large to simulate the full range of effects of the employee relocation including the diversion to different travel paths. Diversion occurs when one travel path becomes so congested that additional travel demand for that path is forced to find an alternate and less congested route. For this study, attention was given to capturing the effects of diversions to or from Route 3, Route 128, Route 62, and Route 4/225. Figure 1-2 depicts the study area roadway network.

FIGURE 1-1
Study Area

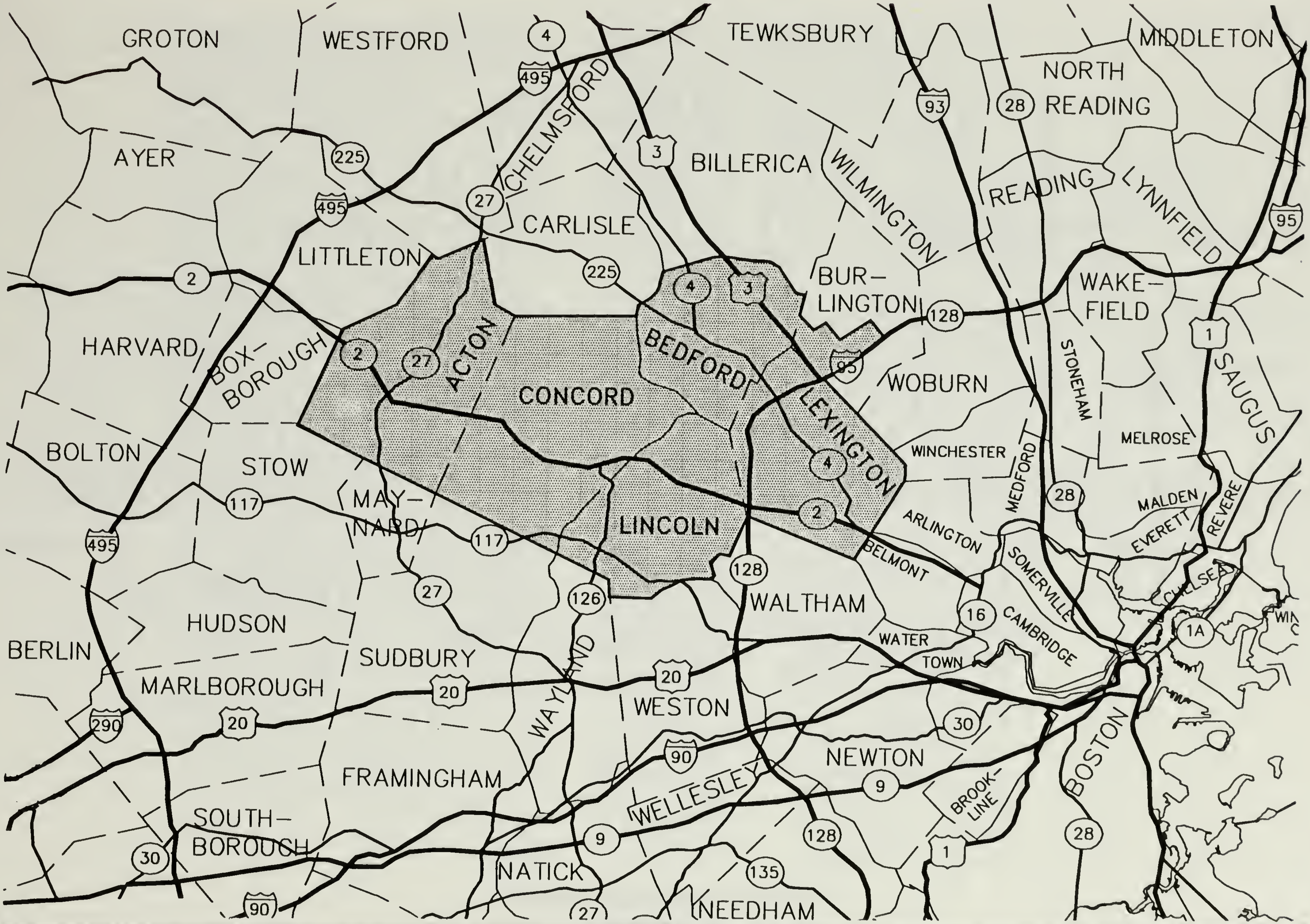
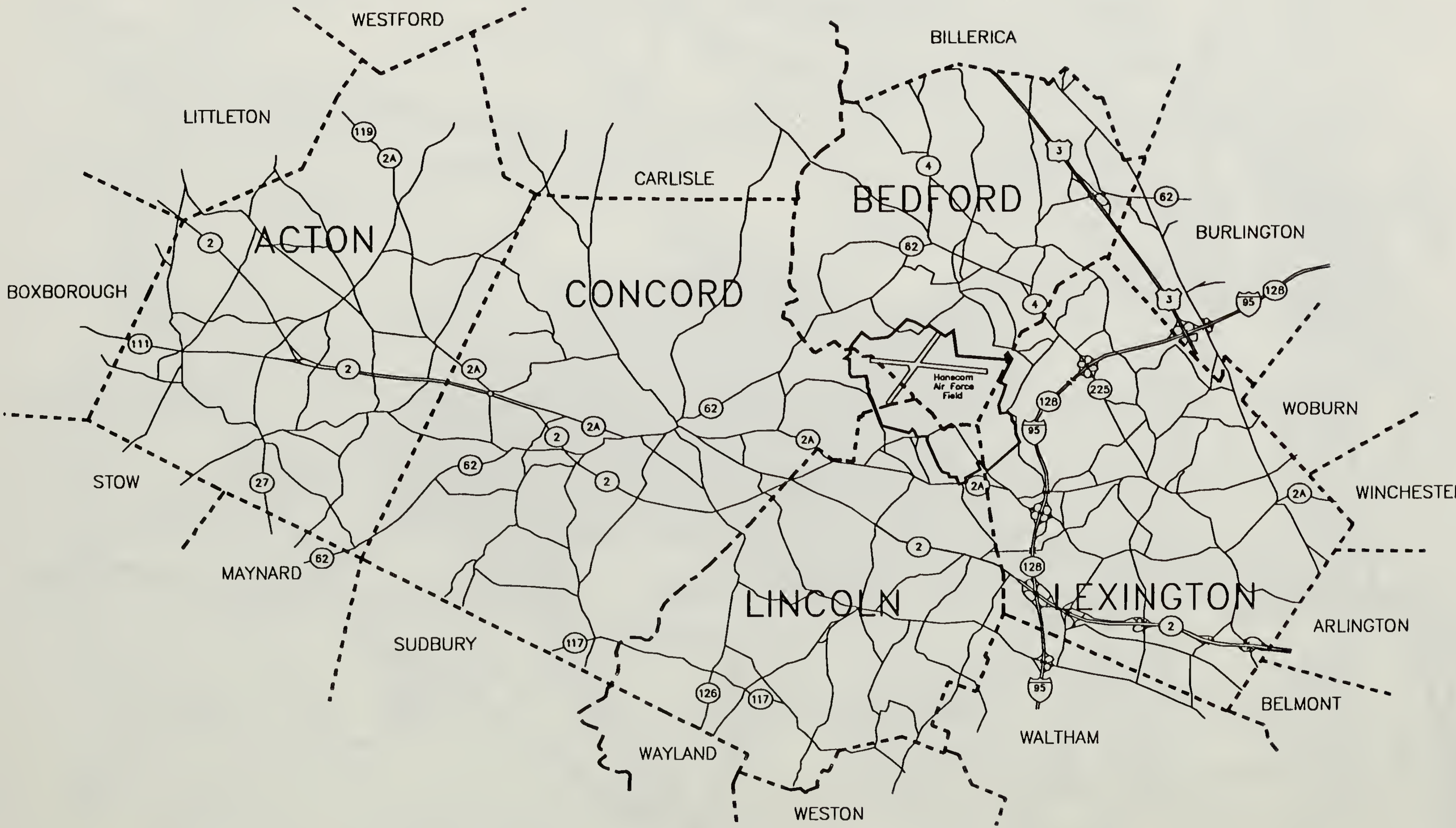


FIGURE 1-2
Study Area Roadway Network



2 EXISTING CONDITIONS

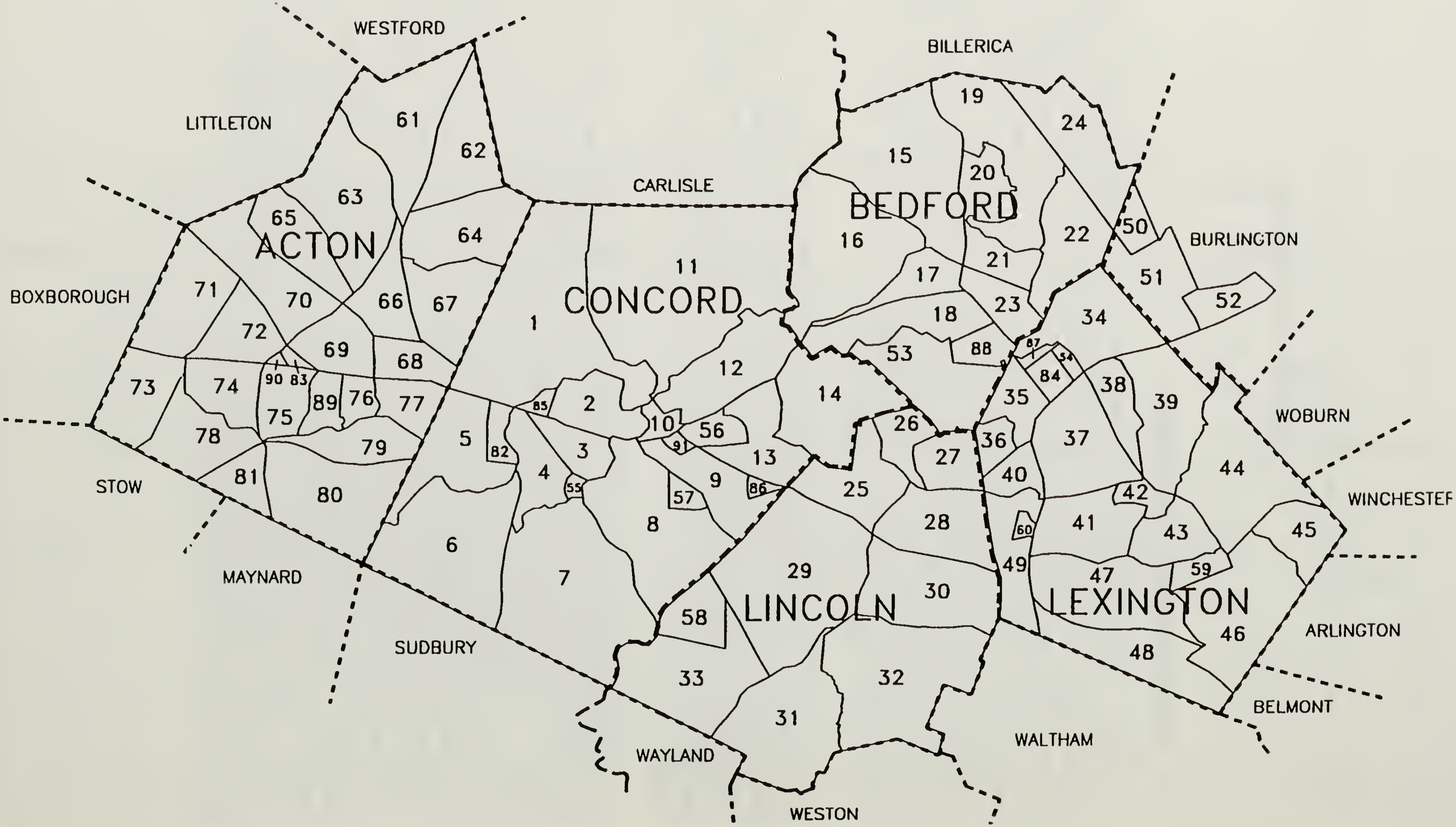
2.1 SOCIOECONOMIC CONDITIONS

The study area, which includes the towns of Acton, Bedford, Concord, Lexington, Lincoln, and a small portion of western Burlington has been divided into smaller areas which are referred to as traffic zones (See Figure 2-1). For purposes of travel demand modeling, it is necessary to estimate the number of households, retail employees, and non-retail employees for each traffic zone in the study area. This information is utilized to estimate the trip generation and trip distribution on the travel demand network. In the base year of 1990 there were an estimated 29,360 households and 82,139 employees internal to the study area. (Note that these totals include only that portion of Burlington, internal to the study area.)

When the 1990 socioeconomic data was developed, the 1990 U.S. Census information was not yet available. So, for Bedford, Burlington, Concord, Lexington and Lincoln the town total 1990 households were estimated by adding any newly constructed and occupied households between 1989 and 1990 to the 1989 household estimate previously completed for the HAFB employee relocation study.

For the town of Acton, which was not part of the HAFB study, the 1990 households were estimated utilizing the 1990 U.S. Census Preliminary Population data. Average household size in the study area was estimated to decline by 5.7 percent between 1980 and 1990. As an example, the 1980 average household size in Acton was 2.97, making the 1990 average household size in Acton 2.81. Household size is needed to produce the number of households represented by the population estimate. The location of large housing developments that were constructed between 1980-1990 were identified from Metropolitan Area Planning Council (MAPC) information, Environmental Notification Forms (ENFs), Environmental Impact Reports (EIRs) and other development permit requests. The data was confirmed by the town planner. Town total household growth that occurred between 1980 and 1990, which could not be accounted for by specific project information, was distributed into traffic zones utilizing the distribution found in the 1980 Census block group statistics. The breakdown of households by town is presented below:

FIGURE 2-1
Traffic Zone Structure



Estimated 1990 Households by Town

Acton	6,252
Bedford	3,909
Burlington	7,284
Concord	5,617
Lexington	10,277
Lincoln	3,194
Total	36,533

The U.S. Census population estimates for 1990 (and the later published actual 1990 population) reveal that population growth throughout the study area has remained virtually flat. The number of households in the study area grew by 777 between 1980 and 1990, representing an increase of approximately 2 percent. The growth in the number of households represents a decline in the average household size, not a significant increase in population.

Town total 1990 employment figures were estimated by adding the employment from new developments between 1989 and 1990 to the 1989 Department of Employment and Training (DET) employment statistics. The breakdown of employees by town is presented below:

1990 Employment by Town

	Retail	Non-Retail
Acton	2,564	7,192
Bedford	873	24,161
Burlington	7,293	27,596
Concord	1,520	10,955
Lexington	2,234	17,193
Lincoln	156	1,663
Total	14,640	88,760

The location of existing employment sites within communities, for purposes of estimating traffic analysis zone employment totals, were determined utilizing the following sources:

- Directory of Massachusetts Manufacturers, 1988-1989, Published by George D. Hall

- Massachusetts Service Directory, 1987-1988, Published by George D. Hall

- Employment Wages in Massachusetts Cities and Towns 1980-1989, Department of Employment and Training

- Spaulding & Slye Report of Leasable Office, Industrial, and R & D Space

The DET and Directory sources identifies employers by address, and Standard Industrial Classification Code, while the older hard copy version of the Job Guide also provides the range of number of employees. The Spaulding & Slye Report furnishes building square footage, address, and occupancy rate. This occupancy rate was used to accurately estimate the number of employees at each work site.

Growth in employment throughout the study area has been substantial during the previous decade. Between 1980 and 1990 employment in the six study area towns increased by 23,038 employees from a total of 80,362 in 1980 to 103,400 in 1990. This growth represents a 28.7% increase in employment over 1980 levels.

A listing of the number of households, retail and non-retail employees, and average household income assigned to each traffic analysis zone can be found in Appendix A of this report.

2.2 ORIGIN OF TRIPS TO MIT LINCOLN LABORATORY

The most likely travel paths of the relocated Lincoln Laboratory employees to the base can be estimated based on data which identifies the existing origin (home) of these employees. For this study, such data existed for all (on-base and off-base) Lincoln Laboratory employees. From this data, it was determined that the relocated employees enter the study area via the following distribution of paths.

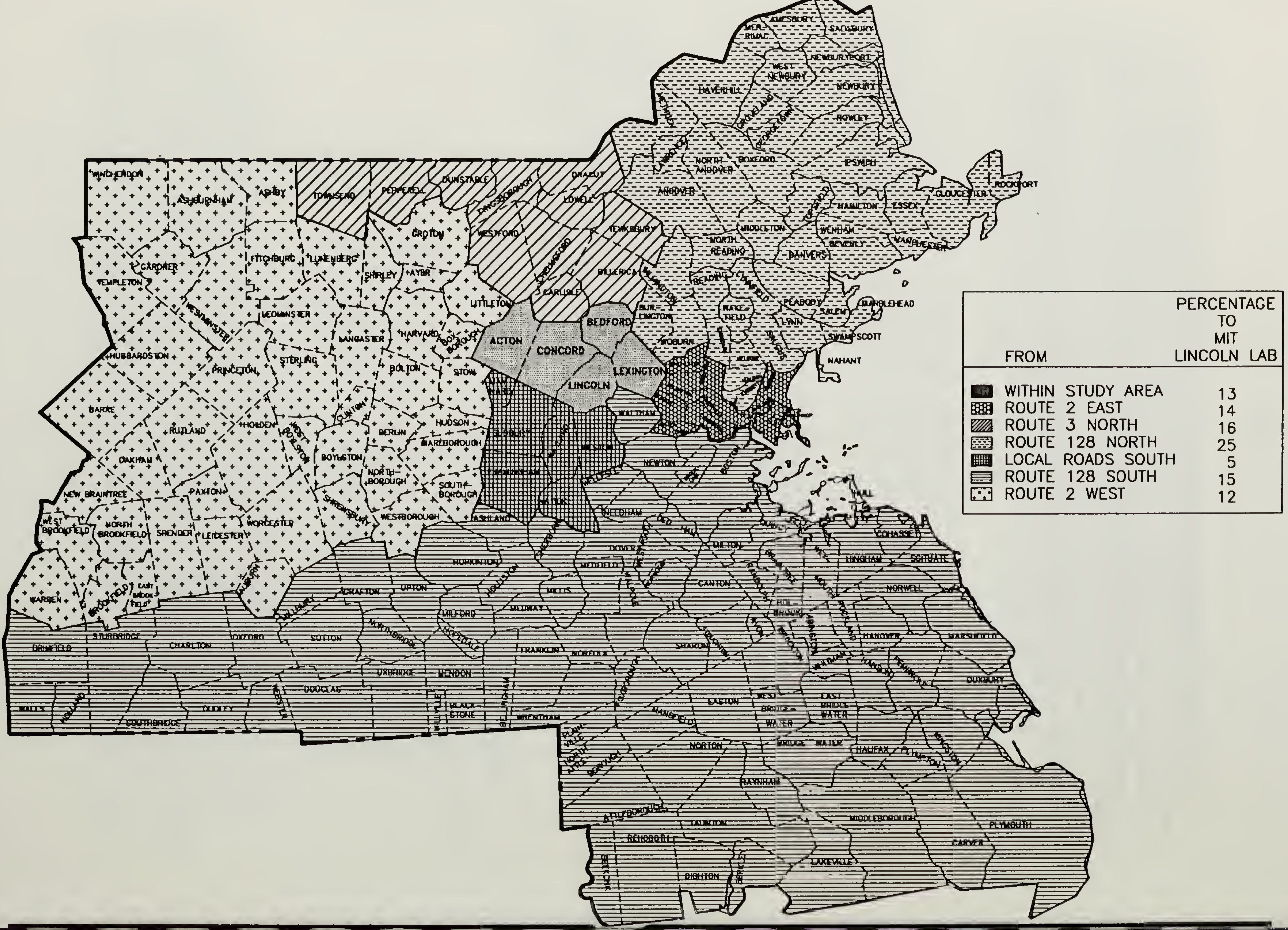
Entry Route	Percent of Trips
	Lincoln Laboratory(All HAFB)
Within Study Area	13%(20%)
Route 2 East	14%(9%)
North (Rt. 3, Rt. 225, Rt.4.)	16%(24%)
Route 128 North	25%(23%)
South (Rt. 126, other local roads)	5%(4%)
Route 128 South	15%(12%)
Route 2 West	12%(8%)

The Lincoln Laboratory employees origin distribution is slightly different from that of the total HAFB employees. The percentage of Laboratory employees with Route 2 and Route 128 entries to the study area (71%) is higher than that of HAFB as a whole (56%). The percentage of Laboratory employees with origins within the study area towns and western New Hampshire towns (29%) is lower than that for HAFB (44%). Generally, the percentage distribution of Lincoln Laboratory employees to study area entry points is more evenly distributed than that of HAFB as a whole.

This distribution was compared to the travel paths of new employee trips which the travel demand model generated in order to validate the accuracy of the model. It was found that the future year assignment of new trips to the base closely matched the zip code distribution listed above.

Figure 2-2 illustrates this distribution of trip origins to MIT Lincoln Laboratory and the likely travel paths of these trips.

FIGURE 2-2
Distribution of Employee Arrivals by Most Likely Travel Route



2.3 TRAFFIC VOLUMES

2.3.1 Data Sources

Traffic count data were obtained from a number of sources. A count program specifically designed for MDPW's Route 2 study was conducted in June 1990 to establish baseline traffic flow information. This program included directional automatic traffic recorder (ATR) counts at 15 locations. These counts were typically of 48 hours duration. Manual turning movement counts were performed at 15 intersections and covered the peak periods of 7-10 AM and 3-6 PM.

Additional traffic count data were obtained from ATR and manual intersection turning-movement counts performed for MDPW's Route 128 Study by CTPS.[3] The Route 128 Short-Range Group at CTPS performed intersection, Route 128 ramp and one Route 128 mainline count in May and June 1990. Actual field count sheets as well as computer spreadsheet files were made available for use in this study.

Traffic count data obtained for the 1989 HAFB study were also utilized. Very briefly, that count collection program included ATR counts at 30 locations and manual turning movement counts at 18 intersections.[4]

Other traffic count data were obtained from the MDPW's statewide traffic counting program. Data from permanent count Station 403, Route 2 in Concord east of the rotary, were used to determine the seasonal fluctuation in traffic volumes. Data from Station 402, Route 20 in Weston east of the Wayland town line, and Station 409, Route 27 in Acton north of the Maynard town line, were also examined for suitability in developing seasonal adjustments factors. Data for these stations were obtained from MDPW's Massachusetts Traffic Volumes 1988.[5] The Route 128 1986 traffic flow map was supplemented by data from Station 14, Route 128 in Woburn south of Route 38, and Station 32, Route 128 in Weston north of I-90. Data for these two stations for 1988 and 1989 were obtained in raw form directly from MDPW computer tapes.

2.3.2 Adjustment and Balancing

In order to establish a baseline traffic flow map, it was investigated whether counts from 1989 had to be factored to 1990 levels. To establish the need for the development of traffic growth factors, locations in the study area that had traffic counts available for two or more years were examined. Comparisons showed that 1989 to 1990 traffic volume changes vary

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3. Traffic Study for the Route 128 Corridor, North Suburban Section, CTPS, ongoing.

4. For more information on data sources, adjustments and balancing of the 1989 HAFB, refer to Hanscom Air Force Base Employee Relocation: Traffic Impact Study, CTPS Draft Report, October 1990.

5. The introduction of this document provides an explanation of the MDPW's count program.

slightly from location to location and between specific movements from the same location. Generally, there was no or very little growth in traffic volume between the two years. Also, a number of locations had experienced a drop in traffic volumes, mostly in the PM peak hour. As a result of the investigation, it was decided to apply no growth factors to 1989 data.

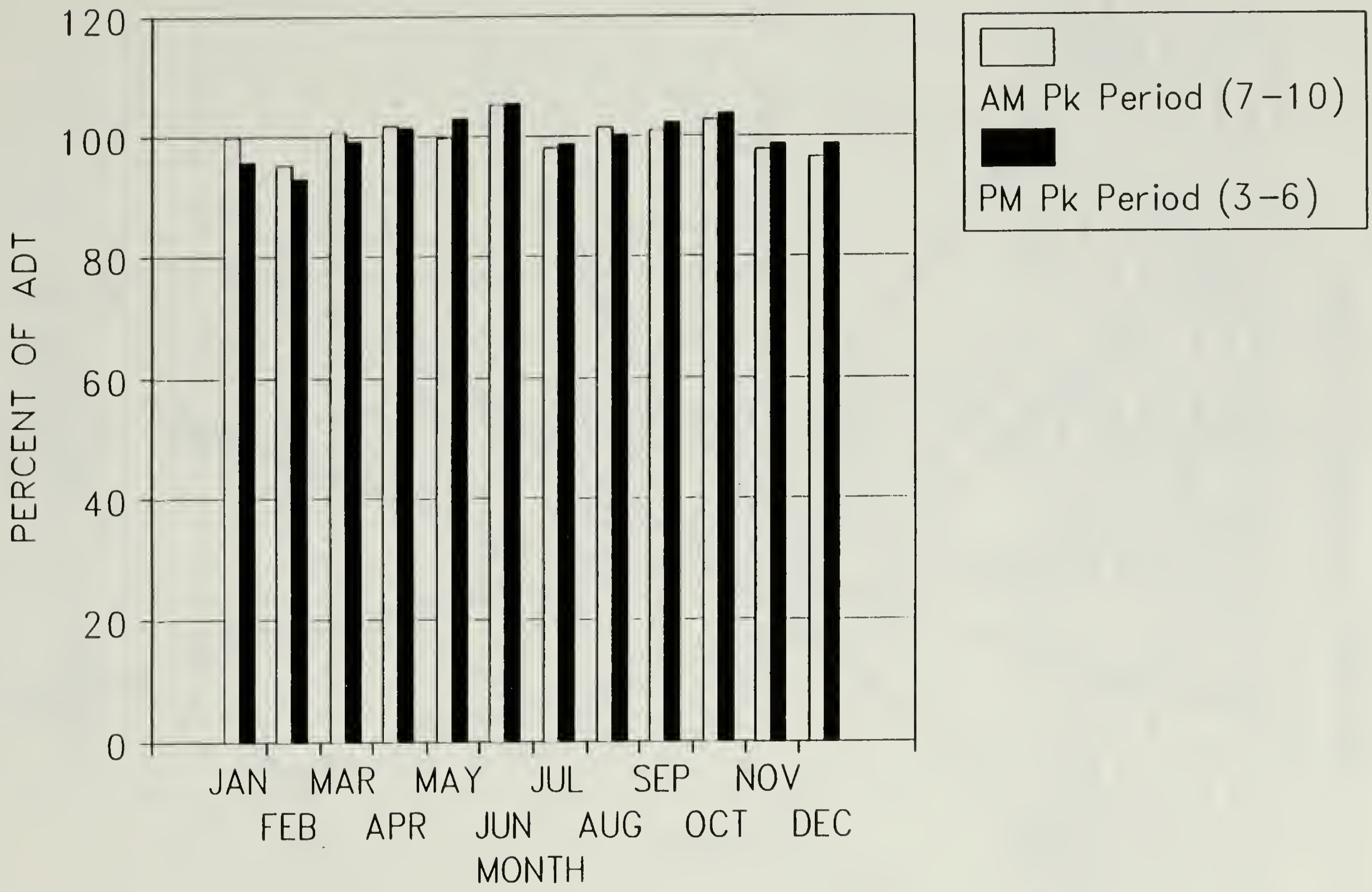
Day-of-Week and Monthly Adjustment

Raw traffic data must be adjusted to account for seasonal and daily fluctuations (i.e., the data must be normalized to reflect typical operating conditions within the study area). For this study, raw daily traffic volumes from 1989 and 1990 were adjusted to represent 1990 Average Annual Weekday Traffic (AAWDT) conditions. Ideally, yearlong traffic data for several different types of roadway facilities at locations throughout the study area would be available for this purpose. In this study area, MDPW Stations 402, 403, and 409 are the only sources of continuous count data. Due to their distance from the primary study area, the data from Stations 402 and 409 were not used. Thus, Station 403, Route 2 in Concord east of the rotary, provided the sole source of data for determining the seasonal fluctuation in traffic volumes. Adjustment factors for each month were developed for the AM and PM peak periods (7-10 AM and 3-6 PM, respectively) for 1988. The monthly fluctuation at this location is minimal (see Figure 2-3) and results in small monthly adjustment factors. The day-of-week fluctuation in traffic volume, determined in a manner analogous to that described above for monthly fluctuation, was found to be inconsequential. No adjustments for day-of-week variation were made for this study.

Count Balancing

After individual counts were factored to 1990 levels and normalized to reflect 1990 AAWDT operating conditions, inconsistencies existed between counts taken at adjacent intersections and roadway segments. These inconsistencies, which are not uncommon, resulted in traffic volumes that were "unbalanced" - i.e., volume entering an intersection did not equal volume exiting. Unbalanced traffic flows may be the result of several factors (e.g., seasonal or time-of-day peculiarities, counts done on different days, counting errors, etc.), and must be removed in order for the modeling process to proceed in an efficient manner. In those instances where an inconsistency could be traced to a specific source, such as a driveway to a major development, the difference was reconciled by adding a new zone, zone connector, or link to the model network. Subsequently, a computer program that statistically minimizes the overall change to the counts while balancing the counts at each intersection was employed. The balanced counts produced by this process were consistent within intersections and between adjacent highway links unless a traffic zone had been connected to the network between the link pair.

FIGURE 2-3
1988 AM and PM Peak Period Monthly Volume Variation:
Station 403, Route 2 in Concord East of the Rotary



2.3.3 1990 Base Year Traffic Volumes

As a result of the process of collecting, adjusting and balancing intersection and mainline traffic counts, base year mainline and intersection turning movement volumes to be utilized in the model calibration process were developed. Figures 2-4 through 2-13 report the 1990 base year traffic volumes for both the AM and PM peak hours for key intersections in each of the study area towns. These volumes represent the finalized traffic volume counts where available, and the assigned traffic volumes following model calibration where counts were not available. The modeling and calibration process are described in detail in section 3.2.

FIGURE 2-4
1990 AM Peak Hour Traffic Volumes - Acton

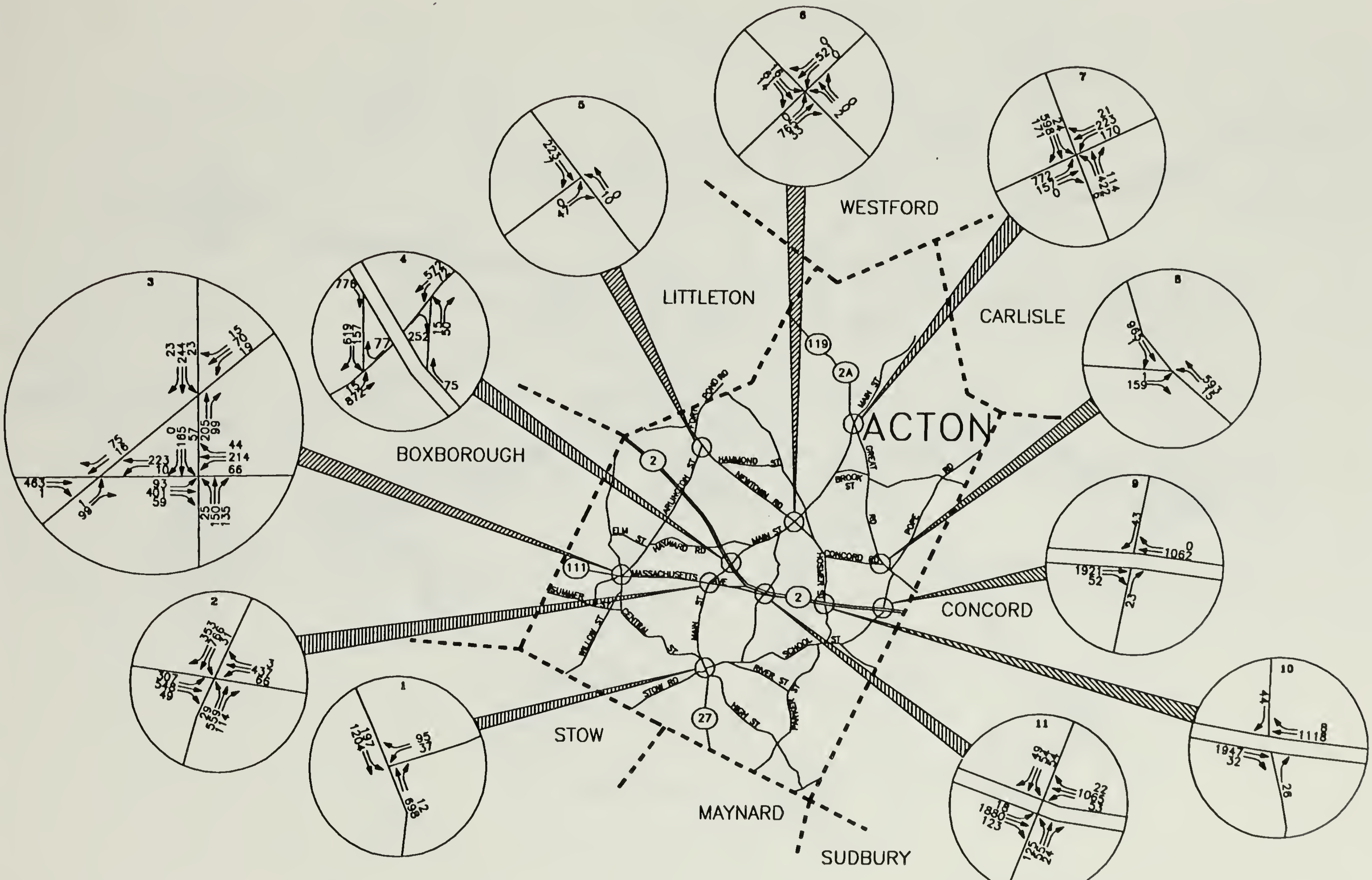


FIGURE 2-5
1990 PM Peak Hour Traffic Volumes - Acton

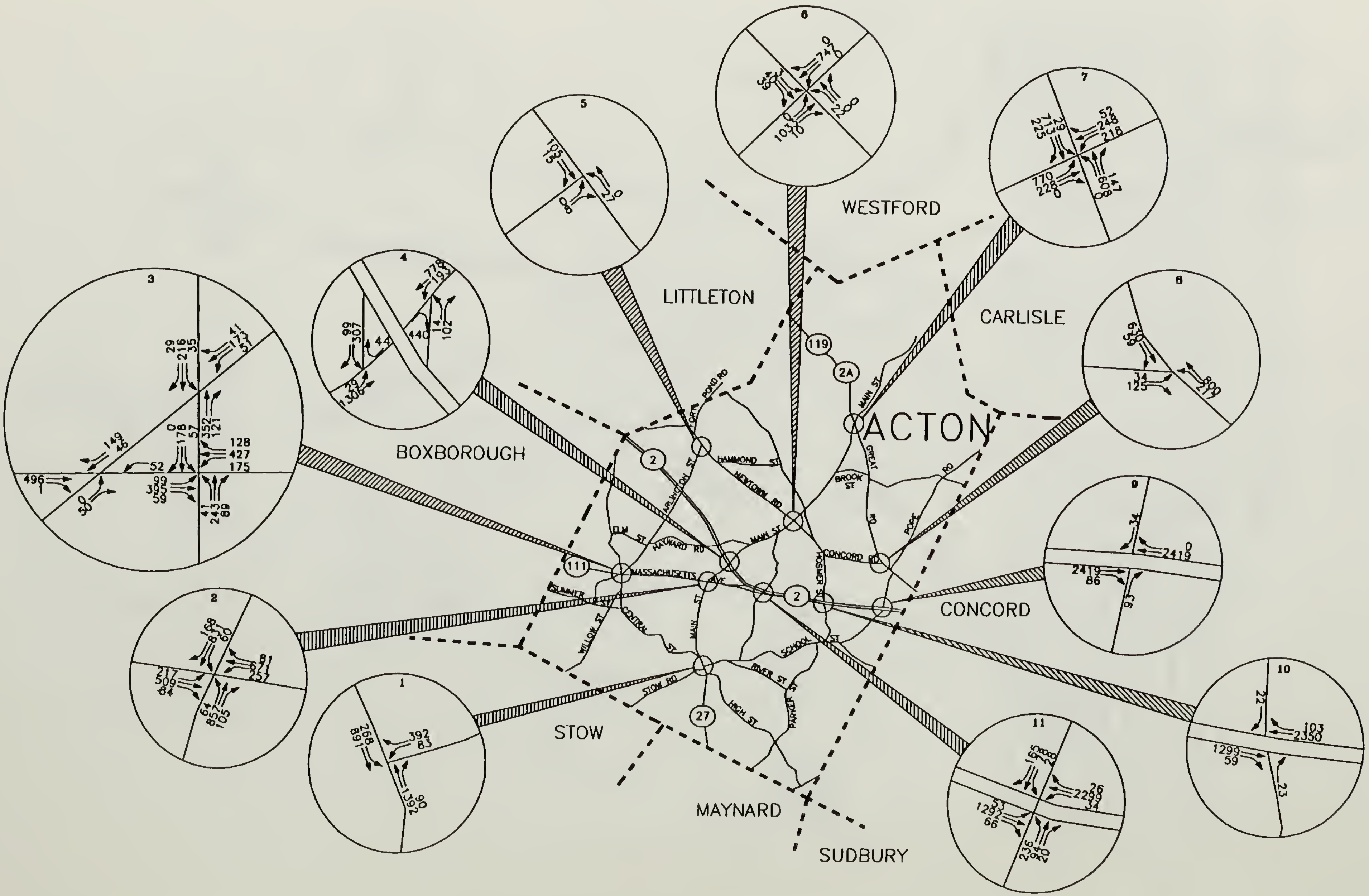


FIGURE 2-6
1990 AM Peak Hour Traffic Volumes - Bedford

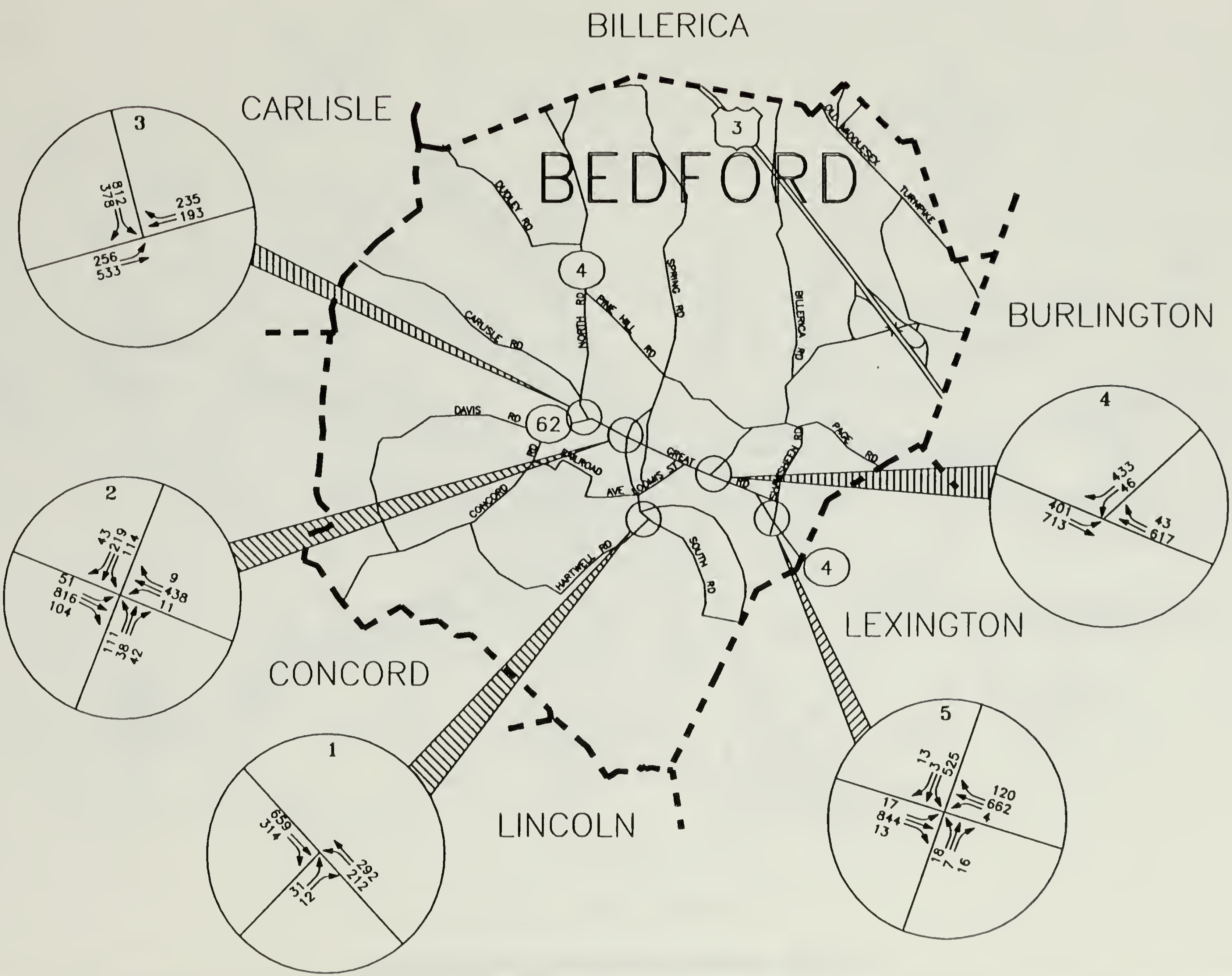


FIGURE 2-7
1990 PM Peak Hour Traffic Volumes - Bedford

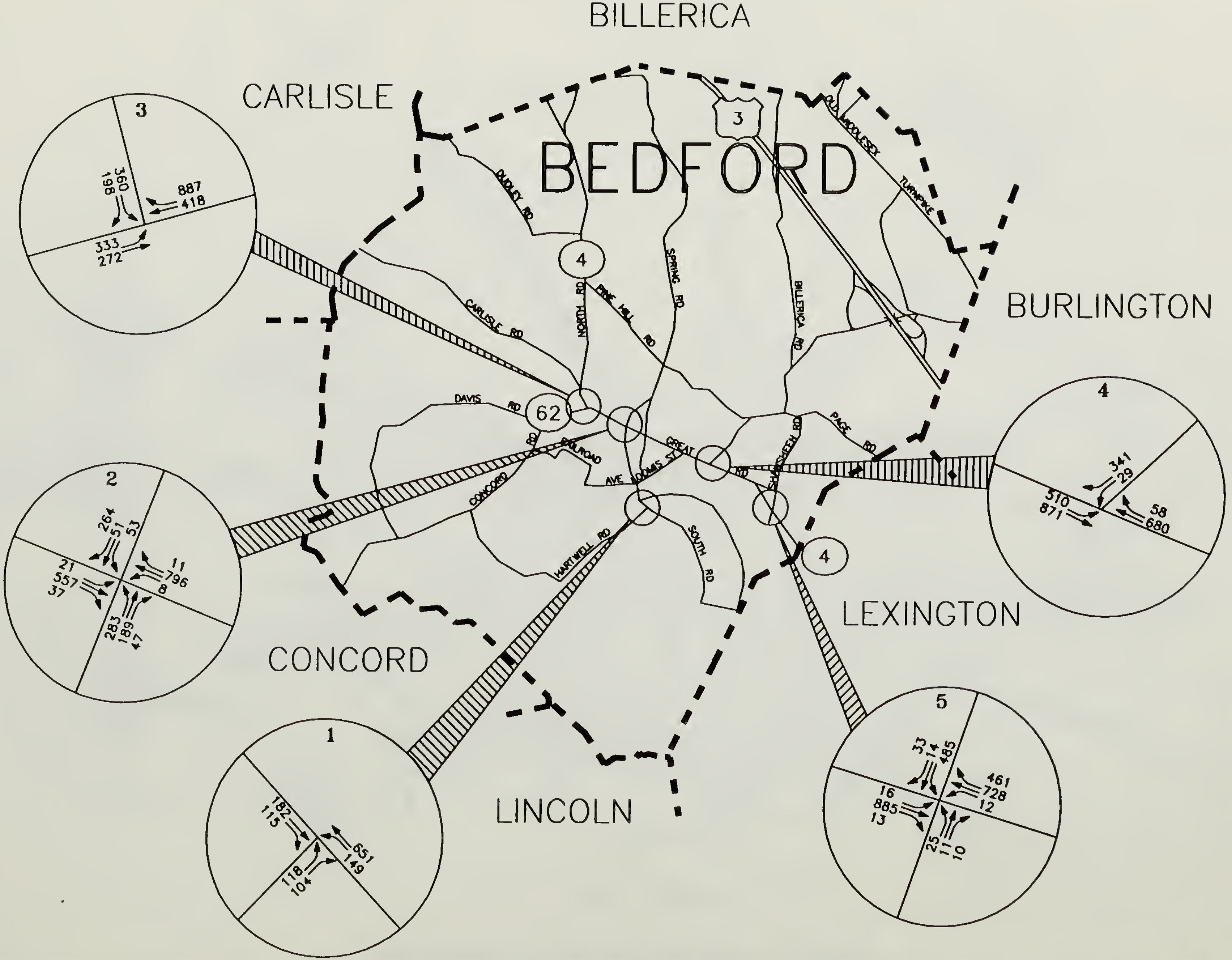


FIGURE 2-8
1990 AM Peak Hour Traffic Volumes - Concord

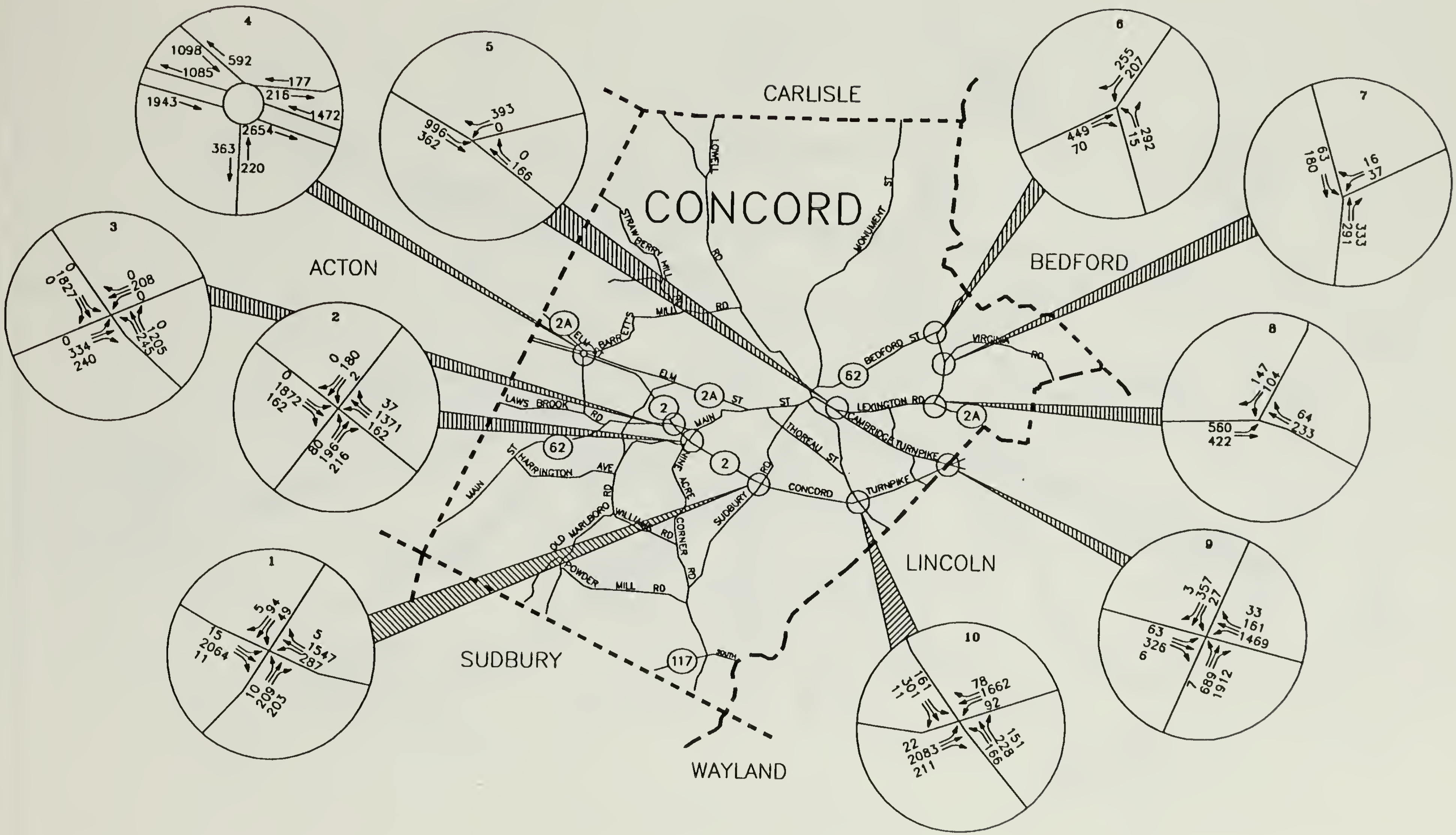


FIGURE 2-9
1990 PM Peak Hour Traffic Volumes - Concord

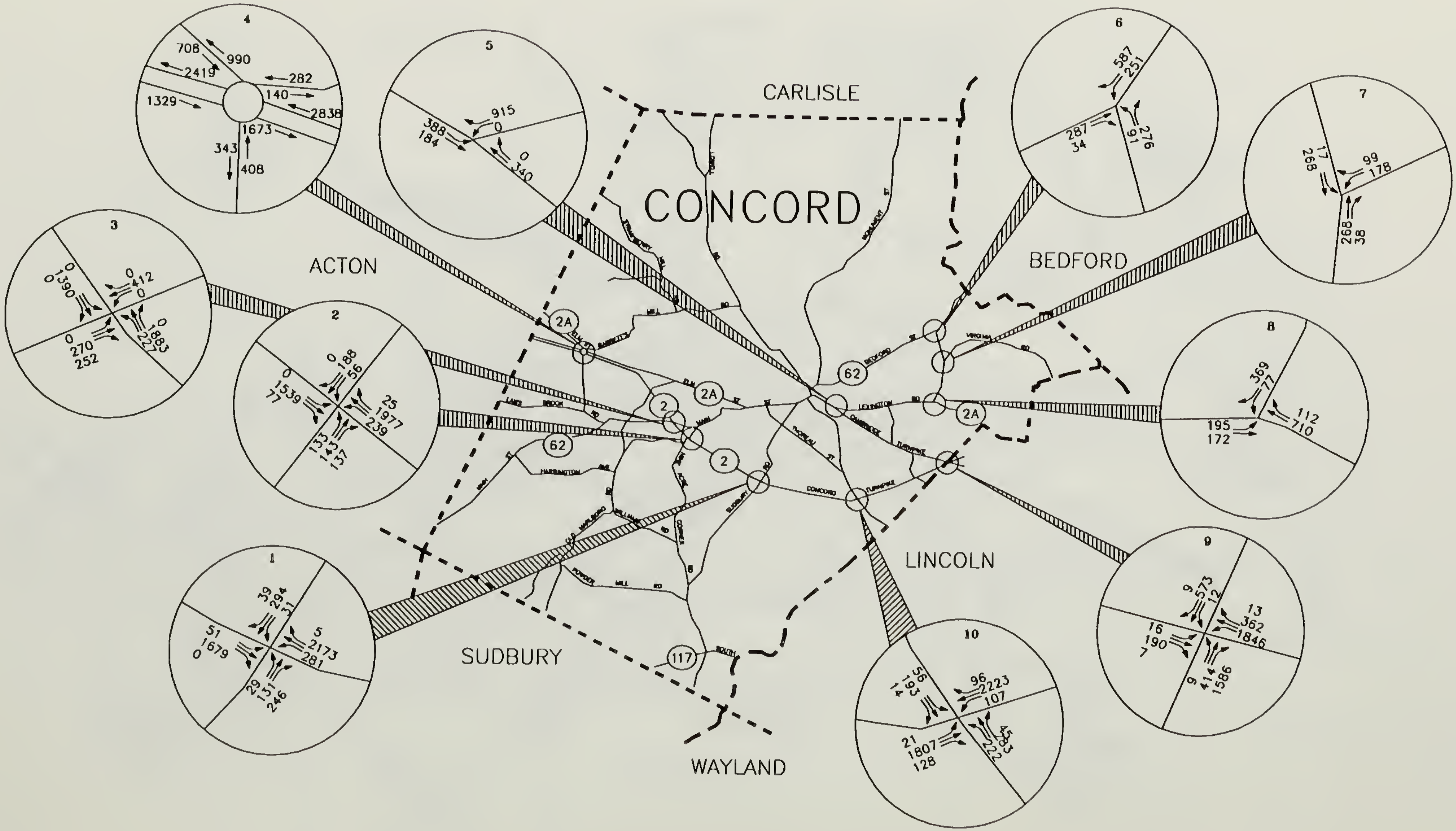


FIGURE 2-10
1990 AM Peak Hour Traffic Volumes - Lexington

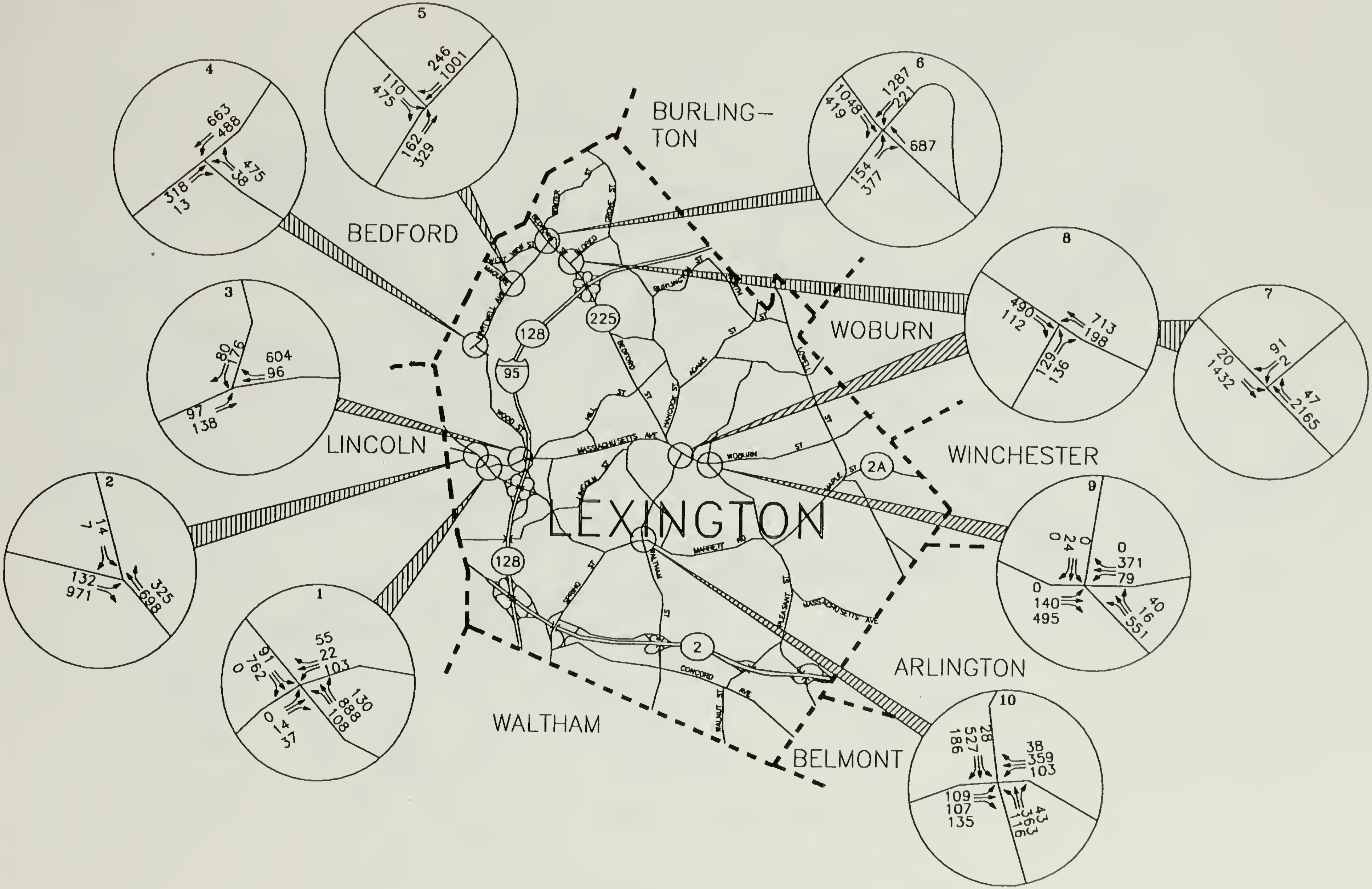


FIGURE 2-11
1990 PM Peak Hour Traffic Volumes - Lexington

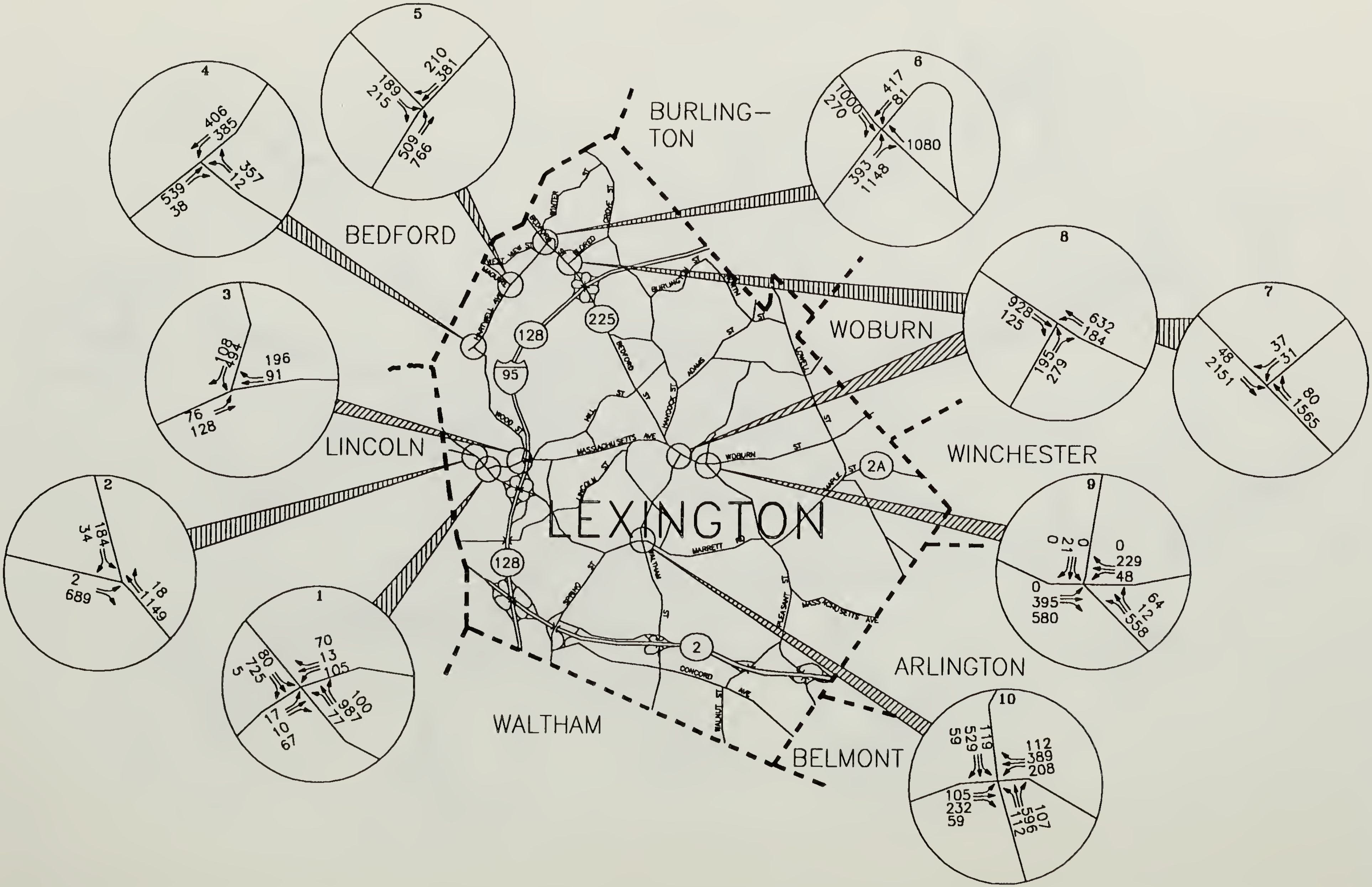


FIGURE 2-12
1990 AM Peak Hour Traffic Volumes - Lincoln

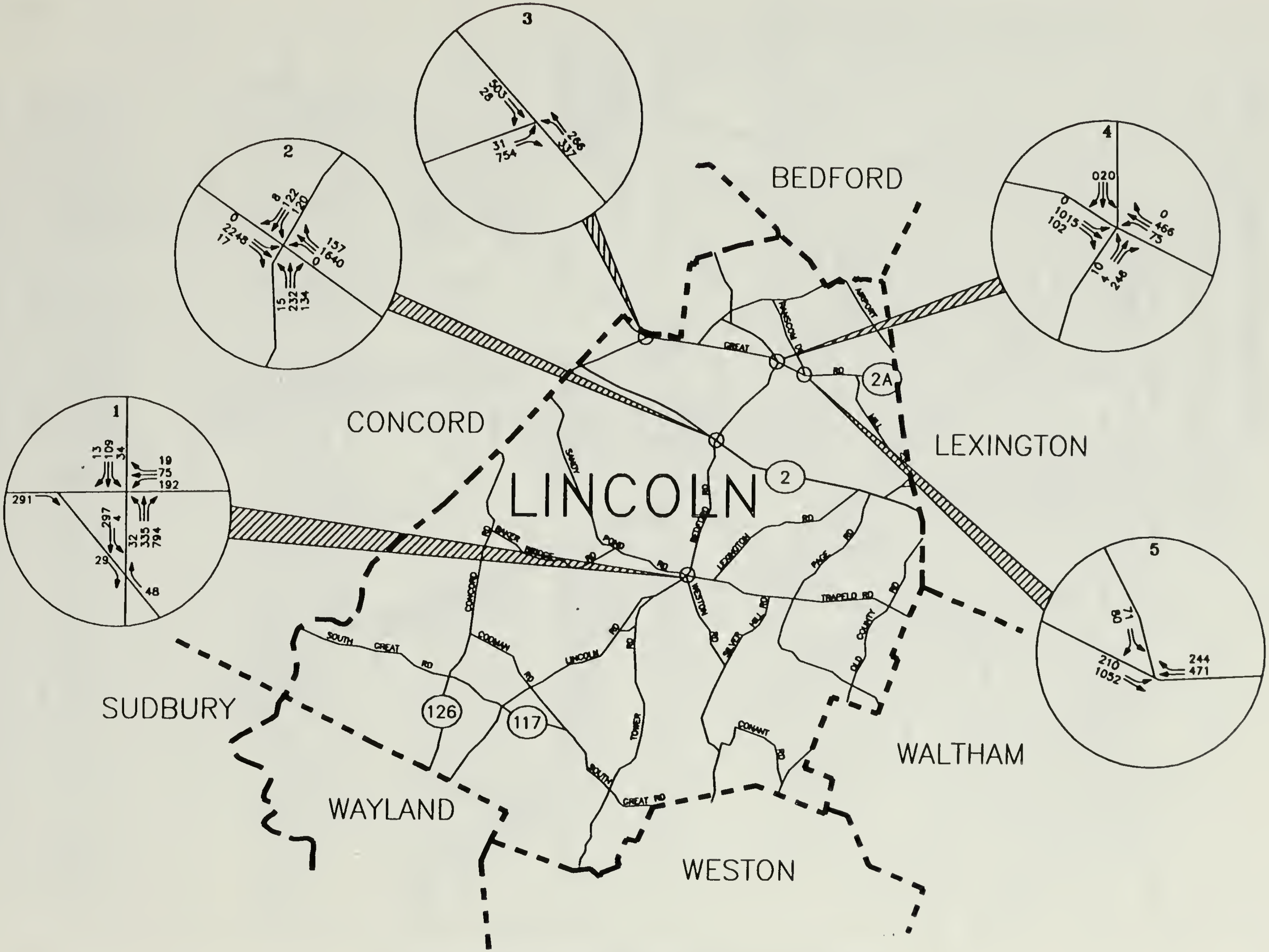
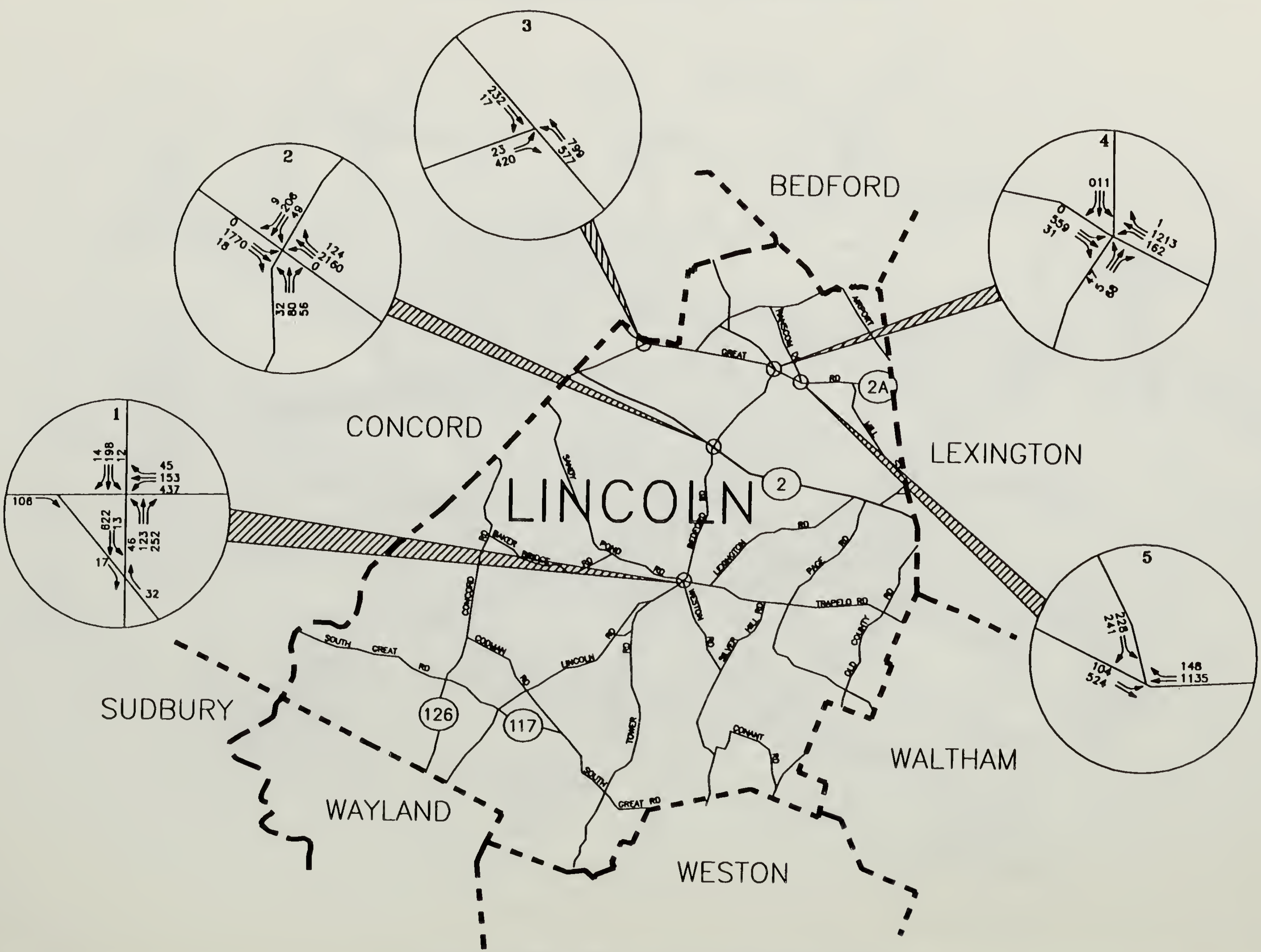


FIGURE 2-13
1990 PM Peak Hour Traffic Volumes - Lincoln



2.4 LEVEL OF SERVICE ANALYSIS

2.4.1 Definition of Level of Service

Roadway and intersection operating conditions are described in terms of a qualitative indicator called level of service (LOS). Determination of LOS is based on several quantitative factors, including capacity, stopped delay at intersections, and average running speed. LOS is graded A through F, with LOS A representing the best possible operating conditions, and lower grades representing progressively poorer conditions. Each grade corresponds to a range of values for a parameter specific to the facility under study (e.g., for arterials the parameter is average travel speed, for signalized intersections it is average stopped delay per vehicle). Tables 2-1 and 2-2 give the typical operating conditions for signalized and unsignalized intersections. (The definition of level of service, Tables 2-1 and 2-2, and all LOS analysis methods used in preparing this study were taken from The Highway Capacity Manual - Special Report 209, Transportation Research Board, National Research Council, Washington, D.C., 1985.)

TABLE 2-1*

Level-of-Service Criteria for Unsignalized Intersections

Reserve** Capacity (PCPH)	Level-of Service	Expected Delay to Minor Street Traffic
>400	A	Little or no delay
300-399	B	Short traffic delays
200-299	C	Average traffic delays
100-199	D	Long traffic delays
0- 99	E	Very long traffic delays
#	F	#

\# When demand volume exceeds the capacity of the lane, extreme delays will be encountered. Queuing may cause severe congestion affecting other traffic movements in the intersection. This condition usually warrants improvement to the intersection.

* Caution should be used in the interpretation of these criteria. They are stated in general terms without specific numeric values. It is, therefore, not possible to directly compare an unsignalized LOS with a signalized LOS in terms of specific delay values without collecting delay data directly at the site. These levels of service are not associated with the delay values cited for signalized intersections.

** Reserve, or unused, capacity is the difference between the theoretical maximum capacity of a lane and the observed traffic volume currently using that lane. It is measured in passenger cars per hour (PCPH).

TABLE 2-2

Level-of-Service Criteria for Signalized Intersections

Level of Service	Average Stopped Delay (sec/vehicle)	Operating Characteristics
A	<5	Most vehicles arrive during the green phase, and progression is extremely favorable. Most vehicles do not stop at all.
B	<15	More vehicles stop than for LOS A, causing higher levels of average delay. Progression is generally good.
C	<25	Progression is fair. Individual cycle failures may appear. The number of vehicles stopping is significant, although many still pass through the intersection unimpeded.
D	<40	The influence of congestion is more noticeable. Many vehicles stop, and the proportion of vehicles not stopping declines. Individual cycle failures are noticeable
E	<60	This is considered the limit of acceptable delay. Individual cycle failures occur frequently.
F	>60	This is considered to be unacceptable to most drivers. Often occurs with oversaturation, i.e., when arrival flow rates exceed the capacity of the intersection. Many individual cycle failures occur.

2.4.2 General Observations

It is important to note that the majority of traffic counts used for this analysis were collected in June 1990. By that time the economic recession in Massachusetts had already affected businesses in the study area resulting in building vacancies and employee layoffs. Comparison between the 1988 and 1989 traffic counts used for "Hanscom Air Force Base Employee Relocation: Traffic Impact Study" and those of 1990 clearly indicated a reduction. The percentage reduction varies by movement depending on the travel path used by former employees. Undoubtedly, the reduction in travel demand for certain turning movements affected the choice of travel paths for the remaining drivers causing shifts in their travel patterns. The overall effect of the 1990 traffic volume reduction and the altering of travel paths was to free up capacity and cause a general improvement in the intersection level of service.

The analyses which follow encompass three clusters of interrelated signalized and unsignalized intersections. These three clusters are located on or around Rt. 2A south of HAFB, Hartwell Av., and Rt. 4/225 in Bedford. Approaches at the signalized intersections and at least the minor approaches of the unsignalized intersections in these clusters are currently operating at marginally acceptable or unacceptable levels of service. Capacity deficiencies are widespread in all three clusters and result in long queues and delays.

2.4.3 Signalized Intersections (Table 2-3)

Route 4/225 at Hartwell Avenue

HAFB and the large amount of office space located on Hartwell Av. produce heavy traffic demand at this jughandle intersection. Additional problems are caused by its proximity to Rt. 128 and the concomitant sharply defined and directional commuter traffic flows.

Analysis using current signal timing shows that during an average signal cycle of the peak hour the approaches operate at acceptable levels of service C and D for both the AM and PM peak periods. The effect of directional commuter traffic is clear at this location, with the AM peak hour dominated by traffic entering Hartwell Av., and the PM peak hour dominated by traffic exiting to Rt. 4/225

Route 4/225 at Shawsheen Road/Pine Street

Field observation at this location indicated that demand at this intersection far exceeds its capacity. PM conditions are such that both the westbound Route 4/225 and the Shawsheen Rd. approaches fail, with long queues. Average stopped delay per vehicle easily exceeds 120 seconds, producing significant aggravation for motorists.

Analysis of existing conditions at this location indicates that the Shawsheen Rd. approach is operating at LOS F, with delays exceeding 120 seconds, in the AM peak hour. The Shawsheen Rd. failure is due to a large number of vehicles turning left onto Rt. 4/225 eastbound and heading towards Rt. 128 and the Hartwell Av. jughandle. The Pine St., Rt. 4/225 eastbound and Rt. 4/225 approaches operate at an acceptable level of service in the AM. In the PM peak hour, the Shawsheen Rd. and Rt. 4/225 westbound approaches operate at an unacceptable level of service. The volume of left turns from Shawsheen is somewhat lower than in the AM but the delay is somewhat higher. The Rt. 4/225 westbound approach operates with delays that exceed 120 seconds and with much greater queue lengths than in the AM, partly because of a large number of right turns to Shawsheen Rd. These right turns are trips headed for points north and west that wish to avoid congestion further west on Rt. 4/225 (and, for those heading to Rt. 3, congestion on Rt. 128 and Rt. 3). The Pine St. and Rt. 4/225 approaches operate at an acceptable level of service in the PM peak hour.

Route 4/225 at South Road/Hancock Street

Field observation at this intersection indicated that demand far exceeds capacity at the Rt. 4/225 approaches in the AM and the South Rd. approaches in the PM. Vehicle delay in the PM on South Rd. exceeded 4 minutes during one visit to this location. The queue for left turns far exceeds the space provided in the exclusive left-turn lane on this approach. The Rt. 4/225 westbound queue extends well back from the intersection and causes interference with turning movements to driveways and other roadways.

Analysis of existing conditions at this intersection reveals that the overall intersection LOS is F for the AM and D for the PM peak hours. In the AM peak hour this failure is caused primarily by heavy eastbound flow on Rt. 4/225. The PM failure is primarily caused by the large number of vehicles turning left from South Rd. A significant portion of these left turns are likely to have originated in the Hartwell Av. area and use South Rd. to avoid congestion at the Hartwell Av. jughandle and on Rt. 4/225. Both these approaches experience extremely long queues during their respective peak hours. This intersection, with its current geometry and signal timing, simply does not have the capacity to process the number of vehicles that desire to use it.

TABLE 2-3

1990 Existing Conditions Level Of Service
Signalized Intersections

Location	AM Peak Hour LOS	AM Peak Hour Average Stopped Delay/Vehicle (Seconds)	PM Peak Hour LOS	PM Peak Hour Average Stopped Delay/Vehicle (Seconds)
Route 4/225 @ Hartwell Av.				
- Hartwell Av.	D	26	D	28
- Jughandle	D	30	D	27
- Rt. 4/225 WB	C	18	D	35
- Rt. 4/225 EB	D	27	C	17
Route 4/225 @ Shawsheen Road/ Pine Street				
- Shawsheen Rd.	F	*	F	*
- Pine St.	B	14	B	14
- Rt. 4/225 WB	B	7	F	*
- Rt. 4.225 EB	B	8	C	20
Route 4/225 @ South Rd./ Hancock Street				
- South Rd.	C	17	F	61
- Hancock St.	C	24	D	37
- Rt. 4/225 WB	B	9	D	28
- Rt. 4/225 EB	F	*	B	13

* Expected average stopped delay per vehicle exceeds 120 seconds.

2.4.4 Unsignalized Intersections (Table 2-4)

Half of the unsignalized intersections analyzed for this study are currently operating at an unacceptable level of service. Of the eight unsignalized intersections, four have an unacceptable level of service for the left turn from the major street approach. Poor LOS for this move indicates that the intersection as a whole is operating poorly, and may also indicate that the major street through movements are suffering delays. The minor street approaches at all of these intersections are, with some exceptions, operating at unacceptable levels of service.

TABLE 2-4

1990 Existing Conditions Level Of Service
Unsignalized Intersections

Location	AM Peak Hour LOS	AM Peak Hour Reserve Capacity	PM Peak Hour LOS	PM Peak Hour Reserve Capacity
Route 2A @ Bedford Road/ Virginia Road				
- Rt. 2A WB LT	C	289	A	483
- Virginia Rd.	E	74	E	31
- Bedford Rd.	E	11	F	-38
Route 2A @ Hanscom Drive (Currently under police officer control in PM - see Section 3.4.3)				
- Rt. 2A EB LT	A	520	NA	
- Hanscom Dr. LT	F	-59	NA	
- Hanscom Dr. RT	A	831	NA	
Route 2A @ Airport Road (Currently under police officer control in PM - see Section 3.5.3)				
- Rt. 2A EB LT	B	349	NA	
- Airport Rd.	E	37	NA	
Route 2A @ Massachusetts Avenue/Minuteman Driveway				
- Rt. 2A NB LT	A	421	A	503
- Rt. 2A SB LT	B	303	B	315
- Massachusetts Av.	F	-175	F	-197
- Minuteman Dr.	F	-4	F	-105
Hartwell Av. @ Wood Street				
- Hartwell Av. WB LT	F	-36	F	-138
- Wood St. LT	F	-38	F	-14
- Wood St. RT	A	479	B	381

TABLE 2-4
Continued

1990 Existing Conditions Level Of Service
Unsignalized Intersections

Location	AM Peak Hour LOS	AM Peak Hour Reserve Capacity	PM Peak Hour LOS	PM Peak Hour Reserve Capacity
Hartwell Av. @ Maguire Road				
(Currently under police officer control in PM - see Section 3.5.3)				
- Hartwell Av. EB LT	E	53	NA	
- Maguire Rd. LT	F	-126	NA	
- Maguire Rd. RT	E	16	NA	
Route 4/225 @ Eldred Street				
- Rt. 4/225 EB LT	E	56	D	104
- Eldred St. RT	F	-43	F	-79
Route 4/225 @ Brooksbie Road (Route 62)				
- Rt 4/225 EB LT	C	246	E	49
- Brooksbie Rd.	F	-378	F	-375

3 FUTURE CONDITIONS

3.1 SOCIOECONOMIC CONDITIONS

Future socioeconomic conditions were defined for the year 1995, which is the estimated year for completion of the MIT Lincoln Laboratory building program. For modeling purposes, it is necessary to forecast the number of households, and retail and non-retail employees in each traffic analysis zone. These forecasts were derived from a variety of data sources and forecasting methodologies.

Future year household forecasts were developed utilizing detailed information about proposed new housing development in each community. All known housing development proposals with completion dates between 1990 and 1995 were included in the forecasts and located in the appropriate traffic zone. Using information on the location of new housing developments allowed for an accurate distribution of the growth in households. The number of future households was determined by adding the existing and known households together. These town totals were then compared to an estimate derived from MAPC (Metropolitan Area Planning Council) forecasts. The number of known housing units which are proposed for development coincided with the number of new households projected from the MAPC interpolated projections.

As a comparison to the known new housing development forecast a 1995 households per zone forecast was developed from MAPC data. MAPC town level population forecasts were interpolated for 1995 utilizing the 1990 Census counts and 2000 population projections. According to the U.S. Census Bureau average household size in Massachusetts decreased by 5.2% between 1980 and 1990. It is anticipated that the households will continue to decrease through the coming decade, but at a much slower rate. Therefore, it was assumed that household size will decrease at only half this rate. This new factor was then divided in half (to estimate the rate for 5 years as opposed to 10 years) and applied to the 1990 household size of each town to estimate the average household size by town for the future year. By dividing the 1995 population estimate by the estimated average household size the population estimate was converted to 1995 households by town.

The housing developments included in the forecasts are listed below:

Town	Traffic Zone	Development Name	Number of Household Units
Acton	67	Duston Lane	4
	74	Great Hill Village	36
	67	Stoneymeade	30
	65	Parlin Park III	18
	64	Bellows Farm	20
	79	Barker's Pond Village	57
	80	Audobon Hill	55
	78	Meadow View	21
	73	Autumn Lane	4
	72	Authentic Homes	6
Bedford	15	Huckins Farm 1	10
	22	Overlook	44
	19	Springs Rd.	15
	16	Revolutionary Ridge Rd.	11
Burlington	Ex	Glenn Cove Park	47
	Ex	Parkhurst Estates I	7
	Ex	Winter Hill Estates	15
	Ex	Brookwood Health Center	100
	Ex	Brookwood Health Center	142
	51	Lexington Estates	4
	Ex	Theresa Avenue	6
	Ex	Center Heights	4
	Ex	C&D Makechnie Road	2
	Ex	Benson Way	3
Concord	7	Williams Road	34
	5	Shell Bluf East	50
	1	Hammersmith	8
	11	Seabury	5
	5	Westvale Meadow	16
Lexington	48	Brookhaven	230
	44	Pheasant Brook I&II	63
	44	Countryside Manor	51
	37	Holderness	6
	37	Turnburry Hill	7
	45	Orchard Crossing	22
	34	Carriage Drive Ext.	12
	34	Royal Circle	6
Lincoln	31	Coburn Farms	9
	32	Adler's Woods	21
	33	Winchell Estates	8
Total			1209

Employment forecasts were developed in a similar manner. Proposed developments that would add new employees within the study area between 1990 and 1995 were identified through

discussion with individual town planners and the Metropolitan Area Planning Council. This research revealed the location, size, and type of proposed new developments. Therefore, it was possible to estimate the number of new employees associated with the developments and to locate those new employees in the appropriate traffic zone. The development related employment growth was then added to the base year employment in each zone. The development-specific employment forecasts were used for this study because they provided the most accurate distribution of employees into the model's traffic zones. The developments included in the forecasts for 1995 were the following:

Town	Zone	Project Name	Sq.Ft.	Employment
Acton	80	Beacon Communication	60,000	138
	61	Heritage Square	12,000	20
	61	3 Pines Realty	3,000	19
	75	Lexington Investment	30,000	144
	61	Acton Indust. Dev.	12,000	58
	62	Acton Foreign Auto	5,000	15
	66	Acton Research Corp.	5,000	11
	80	R and K Realty	23,000	163
	67	D'Angelos	3,000	15
	61	Digital	80,000	385
	66	Lot 3 Techno Drive	35,000	80
	61	High Ridge	200,000	629
	67	Farm Hill	75,000	119
	67	Now & Then	10,000	17
	61	Edgewater	10,000	48
	67	Post Rd. Carpet	6,000	10
	61	Tire Barn	7,000	12
	72	Mitton Constuctors	9,000	43
	62	S.W. Hamilton	6,000	14
	66	NTS	10,000	23
Bedford	24	V. Cerbone	12,000	58
	21	Bedford Auto Site	68,000	172
	24	BASF	80,000	209
	23	Super Stop & Shop	61,000	104
	24	Middlesex Point	12,000	58
	24	Continental Resource	23,000	43
	15	Gould Motors	8,000	14
Burlington	51	Gutierriz Exec.Park	130,000	573
	Ex	Burlington Center I	120,000	529
	52	Filene's	350,000	350
	Ex	Trammel Crow II/III	120,000	529
	Ex	Nixdorf Computers II	54,000	260
	Ex	Nixdorf Computers I	191,000	841
	51	Tambone	215,000	751
	Ex	1 Wheeler Rd.	245,000	857
	Ex	Coen Realty	25,000	163
	Ex	Pay Park Self-Storage	118,000	53
	Ex	Gutierrez	191,000	841

	Ex	20 Wall Street	52,000	250
	Ex	Radionics	5,000	15
	Ex	Cadaro Realty Trust	3,000	10
	Ex	Kwik Kopy	1,000	5
	51	Dundee Park Self-Stor	60,000	10
	51	Gutierrez Retail Ctr	87,000	148
	Ex	Pier 1 Imports	10,000	17
Concord	9	Concord Office Park	150,000	661
	9	Ruggiero's Addition	7,000	31
	13	Concord Museum	9,000	15
Lexington	47	Spring St. Ofc Park	150,000	916
	36	Lincoln Labs	505,000	532
Lincoln	26	Massport	60,000	288
Totals			3,807,000	11,266

The study area household and employment forecasts are presented below. The 1995 employment figures include the Lincoln Laboratory building program. For analysis purposes a 1995 No-Build scenario was developed, which contained all 1995 employment growth except Lincoln Laboratory. Percent change figures representing the household and employment growth between 1990 and 1995 are presented below as well.

	Households			Employment		
Town	1990	1995	%Change	1990	1995	%Change
Acton	6252	6503	4.0%	9756	11719	20.0%
Bedford	3909	3989	2.0%	25034	25692	2.6%
Burlington	7284	7614	4.5%	34889	41091	17.7%
Concord	5617	5730	2.0%	12475	13182	5.7%
Lexington	10277	10674	3.9%	19427	20875	7.5%
Lincoln	3194	3346	4.8%	1819	2107	15.8%
Total	36533	37856	3.6%	103400	114666	10.9%

The purpose of this study was to assess the impacts of the relocation of MIT Lincoln Laboratory employees from off-base leased space to on-base newly constructed space. The building and relocation program will result in an additional 532 on-base employees over 1990 employment levels. The specifics of the building program being assessed are as follows:

New Space to Be Built On-Base

Name	Square Ft.	Employees	Source
MIT South Lab	445,000	532	Off-Base Leased Space
		656	MIT On-Base Space
MIT East Lab	60,000	100	MIT On-Base Space
Total	505,000	1288	

Vacated Off-Base Leased Space

Address	Town	Square Ft.	Employees
40 Hartwell	Lexington	44,000	136
Kilnbrook III	Lexington	75,000	234
4 Maguire Rd.	Lexington	54,000	62
N.E. Tech Center	Concord	62,060	100
Total		235,060	532

3.2 TRAVEL DEMAND FORECASTS - THE MODELING PROCESS

Travel demand forecasts were developed for the two future year scenarios. This study relied on a microcomputer based software package, The Highway Emulator (THE), to develop these travel demand forecasts. This modeling software was developed by Edward J. Bromage of the Traffic Analysis and Design Group at CTPS. Complete documentation of THE is available at CTPS.

Travel demand forecasting is a method of estimating future demand on a transportation system. The underlying concept of travel demand forecasting is the relationship between land use, socioeconomic trends, and travel demand. A travel demand forecasting model consists of a network and an associated zone structure contained within a study area. The network is a representation of the transportation system under study. The zones are representations of the socioeconomic and land-use conditions within them. The internal zones are connected to the network by a zone connector. External zones represent the interface between the study area and the outside world, and are connected to the network at external stations. External zones are aggregate representations of the socioeconomic and land-use conditions and roadway system in the area subtended by the respective external station and are located at those points where major roadways cross the boundary that defines the study area.

The model developed for this study consisted of 91 internal traffic zones and 52 external zones.

The establishment of a network and a zone structure are the preliminary steps in producing travel demand forecasts. Once base-year base-case conditions have been established, the expected future-year network, socioeconomic, and land-use conditions are coded into the model. The actual travel demand forecasting process is traditionally divided into four steps. The following is a brief description of the method The Highway Emulator (THE) uses in each step of the traditional four step travel demand forecasting process.

1. Trip Generation

The first step of the process is to estimate the number of trips that each zone generates. THE relies on the trip generation rates established in NCHRP Report #187[6] (referred to as the QRS Manual). The QRS Manual estimates trip productions and attractions on the basis of zonal household data (number of households and average household income from each zone) and zonal retail and non-retail employment. The QRS manual refines its trip generation estimates through the use of scaling factors based on urban area population. These factors can be used to translate total productions and attractions into auto driver trips, and to distribute 24-hour trip generation estimates to specific time periods.

2. Trip Distribution

This step distributes the generated trips between the model's zones. Traditionally, trips are distributed through the application of an algorithm known as the gravity model. The gravity model distributes trips between zones according to the size (in terms of population and employment) of the zones and the distance between them. Application of the gravity model algorithm produces a trip table, which is a matrix of the trip exchanges between all the model's zones.

3. Mode Split

Mode split is usually performed at this point in the process, but may be done within either the trip generation or trip distribution steps. It consists of categorizing trips according to their mode (highway, transit, bus, taxi, etc.) In THE, auto driver trips are extracted from total trips during trip generation.

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6. National Cooperative Highway Research Program, Report #187: Quick-Response Travel Estimation Techniques and Transferable Parameters User's Guide, Transportation Research Board, Washington, D.C., 1978.

4. Trip Assignment/Model Calibration

THE will calibrate an existing Origin/Destination table (derived from steps 1 and 2) to observed traffic counts. The calibration algorithms employed by THE are based on a maximum entropy algorithm developed and refined by H.J. Van Zuylen and Professor L.G. Willumsen of the University of Leeds.[7] The calibration process is iterative in nature. A trip table is calibrated until the difference between an assignment from it and observed traffic counts is within an acceptable error. Error is calculated in terms of Percent Root Mean Square Error (%RMSE). A %RMSE of less than 10% is generally acceptable, less than 5% is considered very good.

THE uses either a conventional capacity restrained or an equilibrium algorithm to assign a trip table to a network. It is capable of single iteration assignments (all-or-nothing) and multiple iteration assignments. In a multiple iteration assignment each iteration is weighted equally in calculating the final assignment. THE employs Moore's algorithm to determine the shortest path between zone pairs. In the capacity restrained assignment, the BPR (Bureau of Public Roads) curve is used to account for capacity effects on network links. This curve determines the increase in a link's travel time due to an increase in the link's volume-to-capacity ratio. Travel time is developed incrementally by combining the current iteration's travel time with the previous iteration's travel time in a 1:3 ratio.

For this study, the AM peak period base year trip table was calibrated to 2.18% RMSE. The PM peak period trip table was calibrated to 3.43% RMSE. It should also be noted that counts were available for 696 of the 1096 links in the network used for this model. Table 3-1, below, provides a comparison of assigned 1990 and actual traffic counts from 1989 and 1990 used to calibrate the model.

7. Henk J. Van Zuylen and Luis G. Willumsen, The Most Likely Trip Matrix Estimated From Traffic Counts, Transportation Research, Volume 14B, pp 281 - 293.

TABLE 3-1

1990 PM Peak Hour Assigned and Counted Traffic Volumes on Selected Network Links

Location		1990 Assigned	1990 Counts
Wood St. South	NB	454	435
of Hartwell Ave.	SB	405	397
Rt. 2A between	EB	877	869
Old Mass Ave. &	WB	1122	1167
Airport Rd.			
Rt. 4/225 between	NB	1002	1021
Brooksbie & Ashby	SB	1381	1381
Hartwell Av.	EB	1292	1275
South of Maguire	WB	599	596
Rt. 2A West	EB	644	627
of Hanscom Dr.	WB	1331	1376
Hanscom Dr. North	NB	267	252
of Rt. 2A	SB	470	469
Route 2 West	EB	1990	2009
of Crosby's Corner	WB	2431	2426
Main St. between	EB	381	381
Thoreau & Sudbury	WB	868	884
Rt. 4/225 South	NB	1569	1578
of Hartwell Ave.	SB	2231	2229

3.3 1995 FORECAST TRAFFIC VOLUMES

Traffic volumes for 1995 no-build conditions were forecast for the entire study area. Overall traffic volumes are projected to grow by 3% between 1990 and 1995. Figures 3-1 through 3-10 detail 1995 forecast traffic volumes at the intersection level in each of the five study area towns in both the AM and PM peak hours. For comparison to 1990 traffic volumes see Figures 2-4 through 2-13. These forecast volumes at select intersections were utilized for the level-of-service analysis that follows in section 3.5.

FIGURE 3-1
1995 AM Peak Hour No-Build Traffic Volumes - Acton

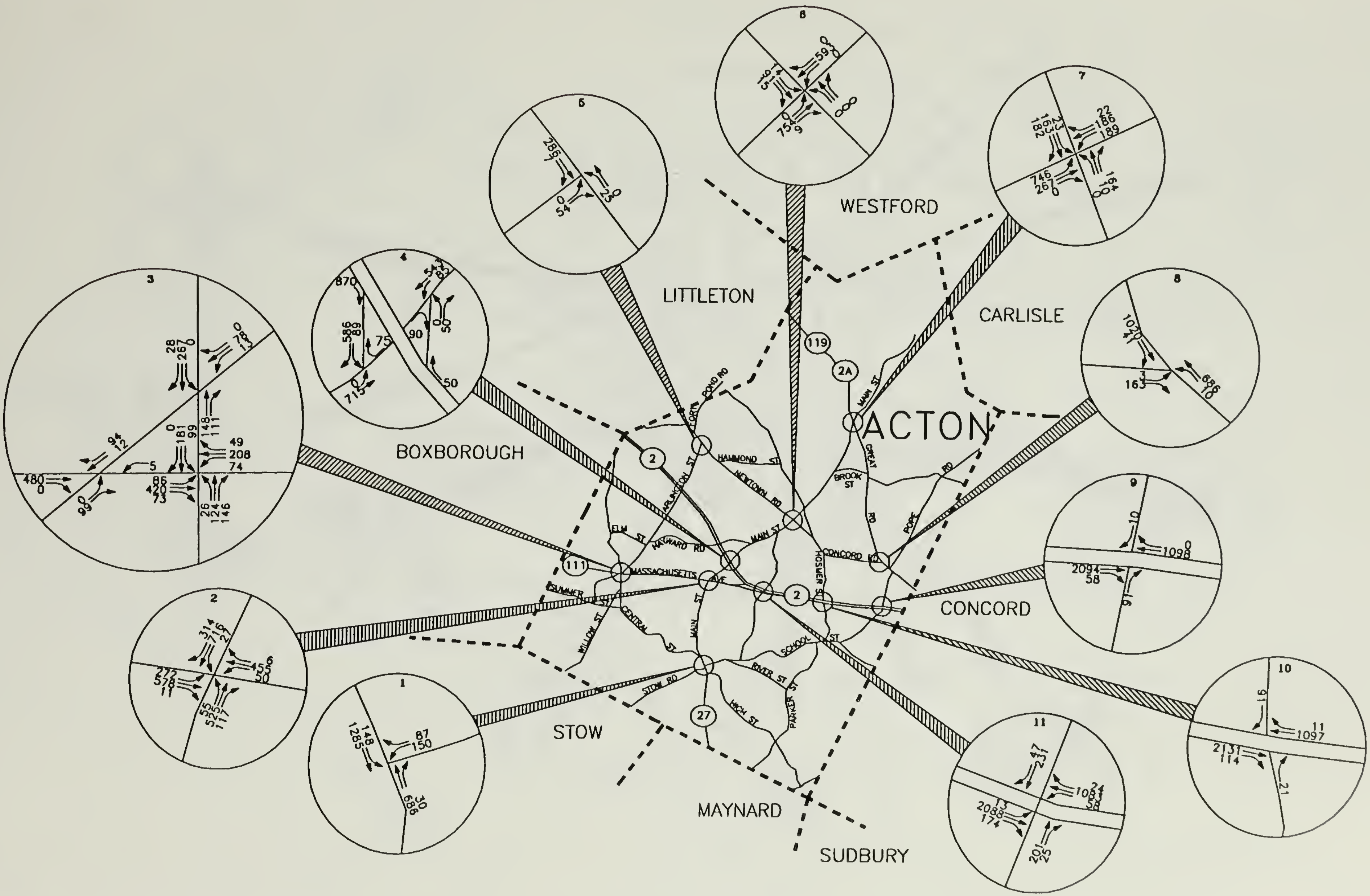


FIGURE 3-2
1995 PM Peak Hour No-Build Traffic Volumes - Acton

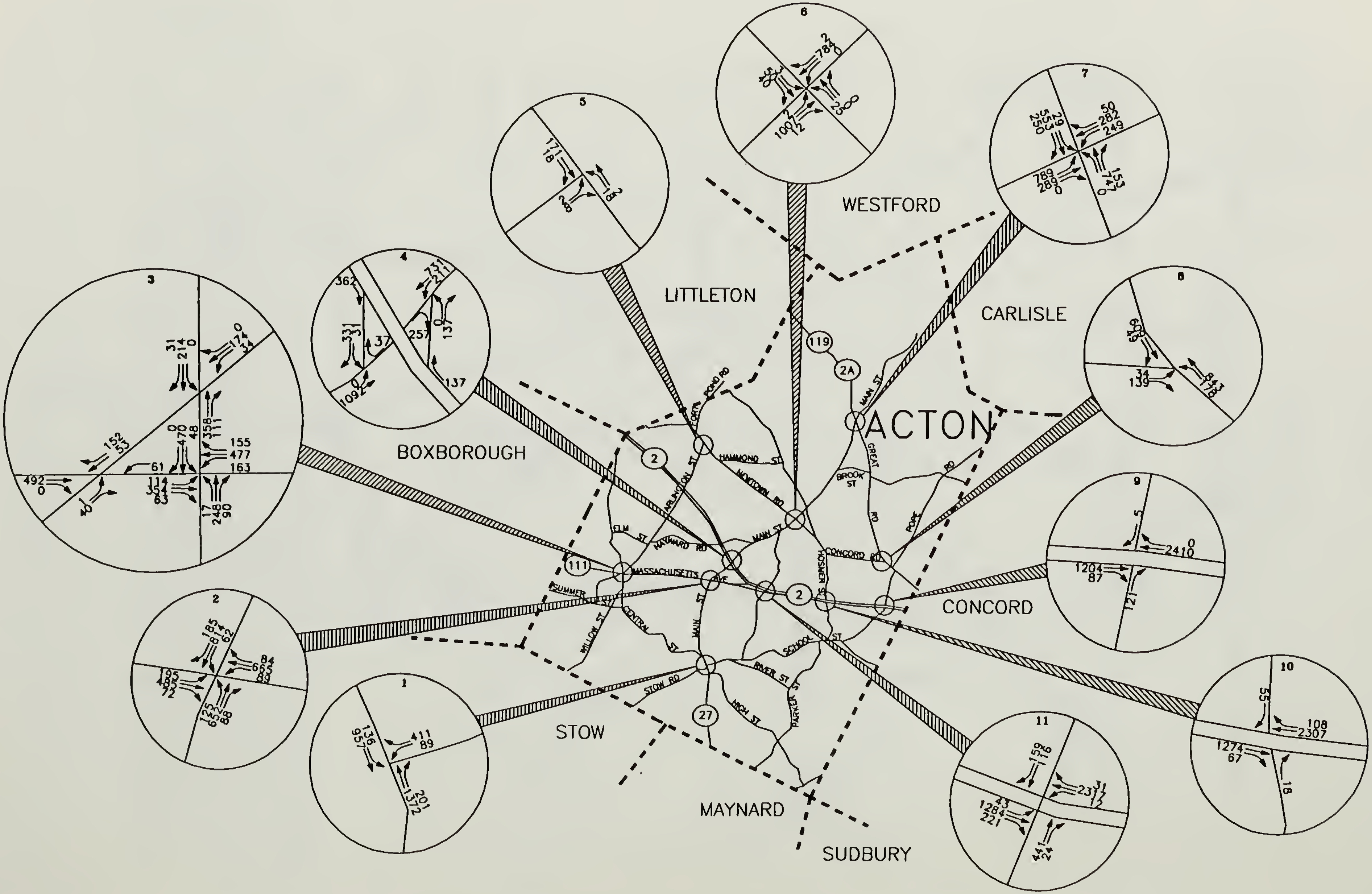


FIGURE 3-3
1995 AM Peak Hour No-Build Traffic Volumes - Bedford

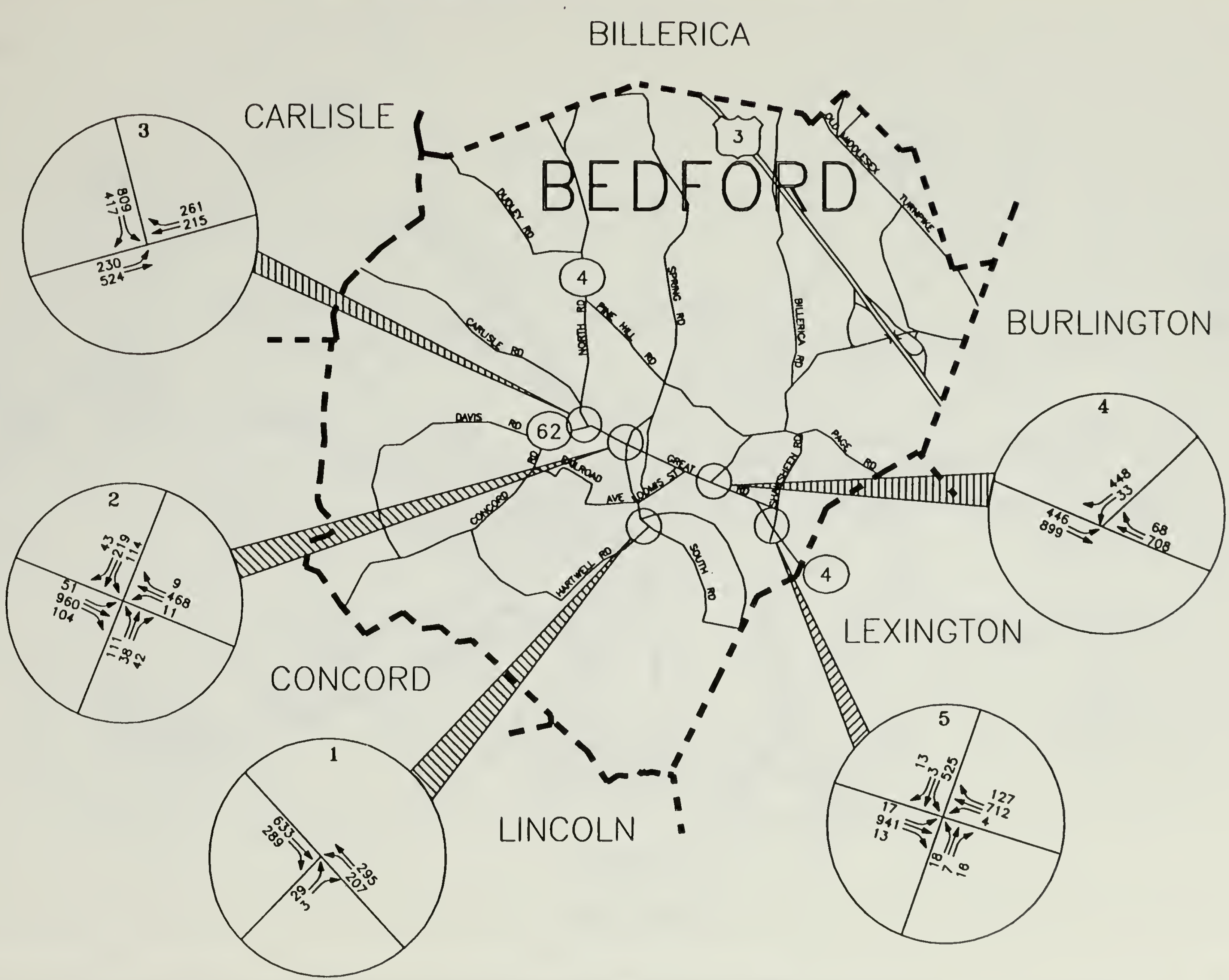


FIGURE 3-4
1995 PM Peak Hour No-Build Traffic Volumes - Bedford

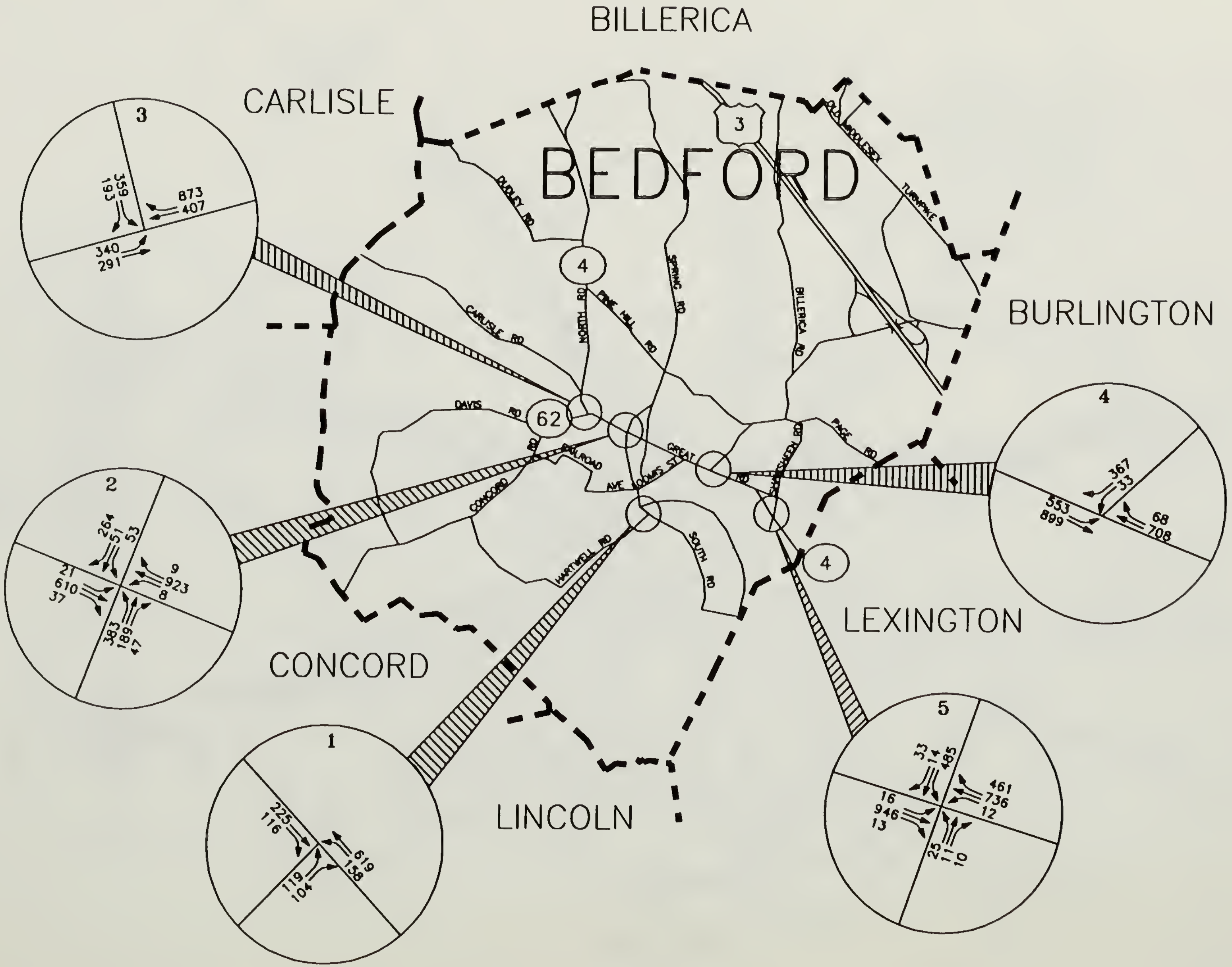


FIGURE 3-5
1995 AM Peak Hour No-Build Traffic Volumes - Concord

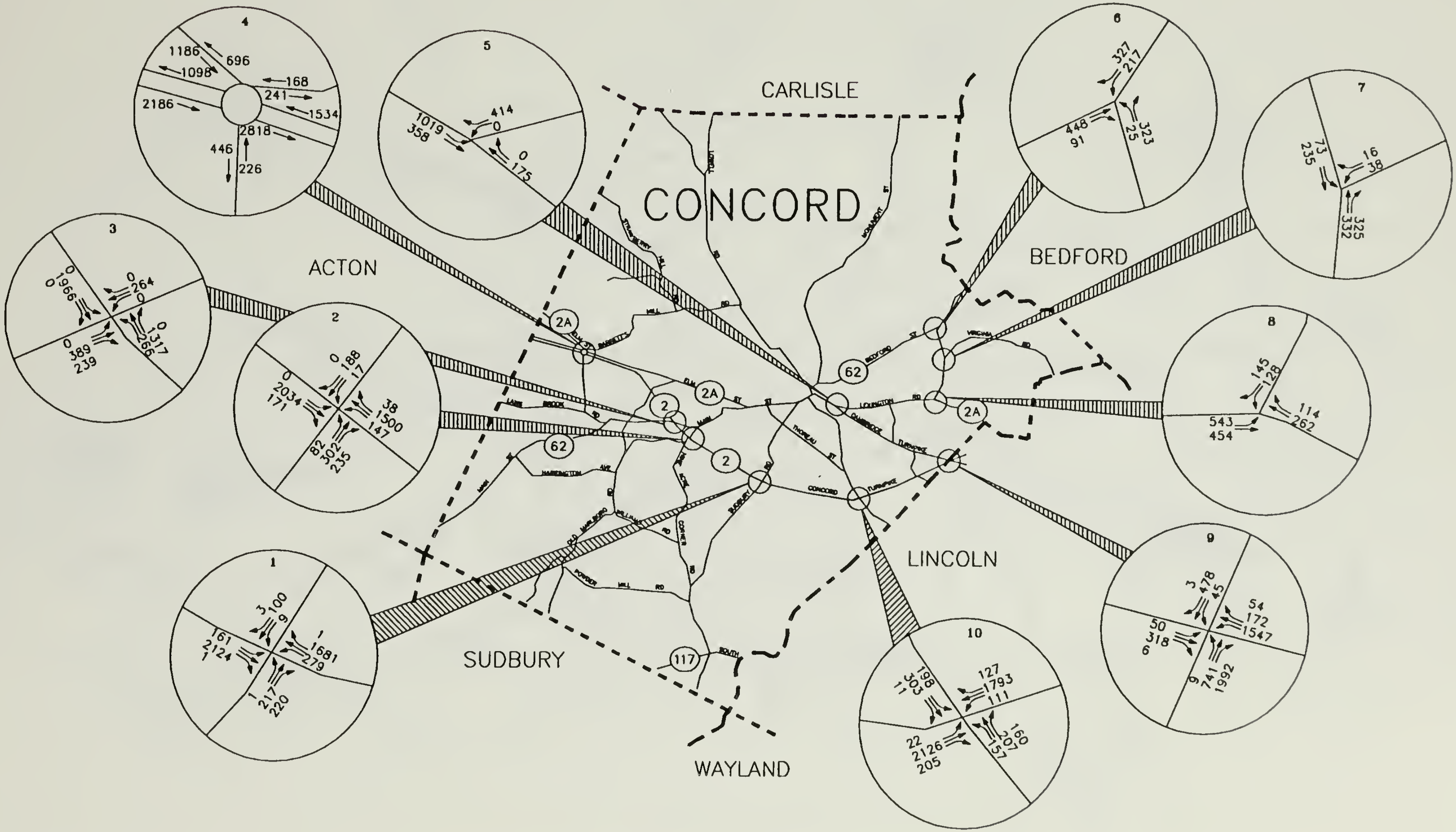


FIGURE 3-6
1995 PM Peak Hour No-Build Traffic Volumes - Concord

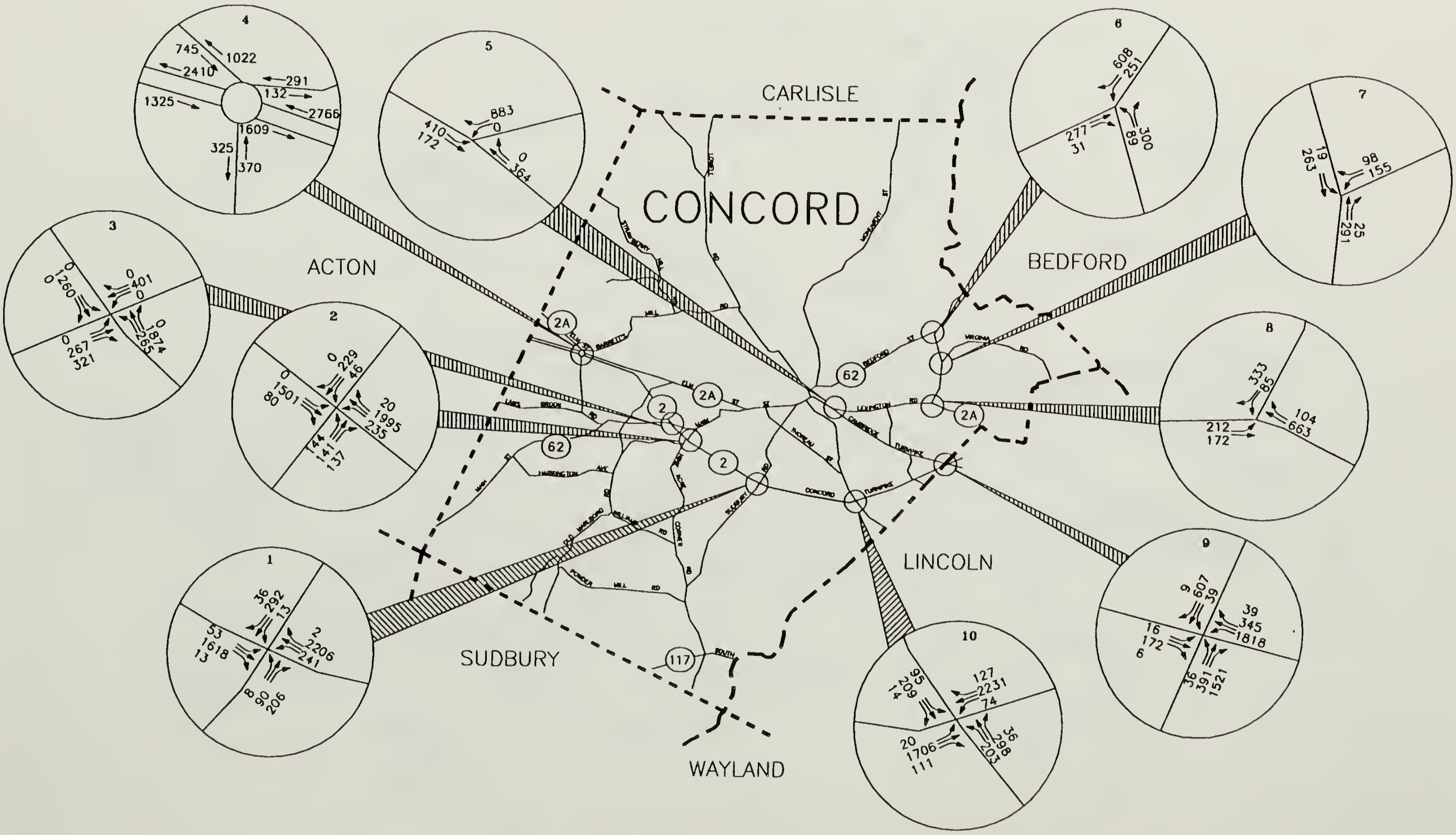


FIGURE 3-7
1995 AM Peak Hour No-Build Traffic Volumes - Lexington

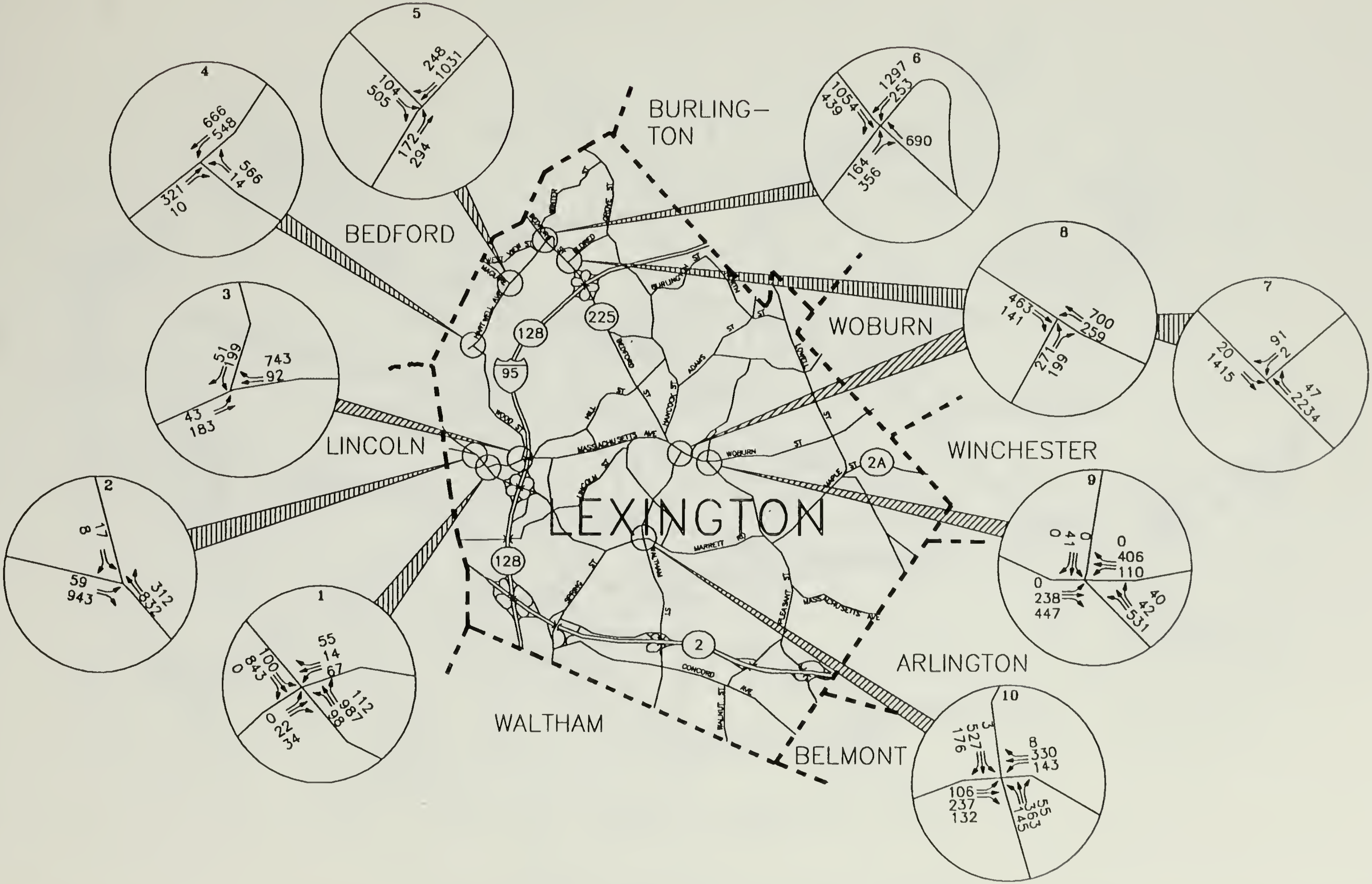


FIGURE 3-8
1995 PM Peak Hour No-Build Traffic Volumes - Lexington

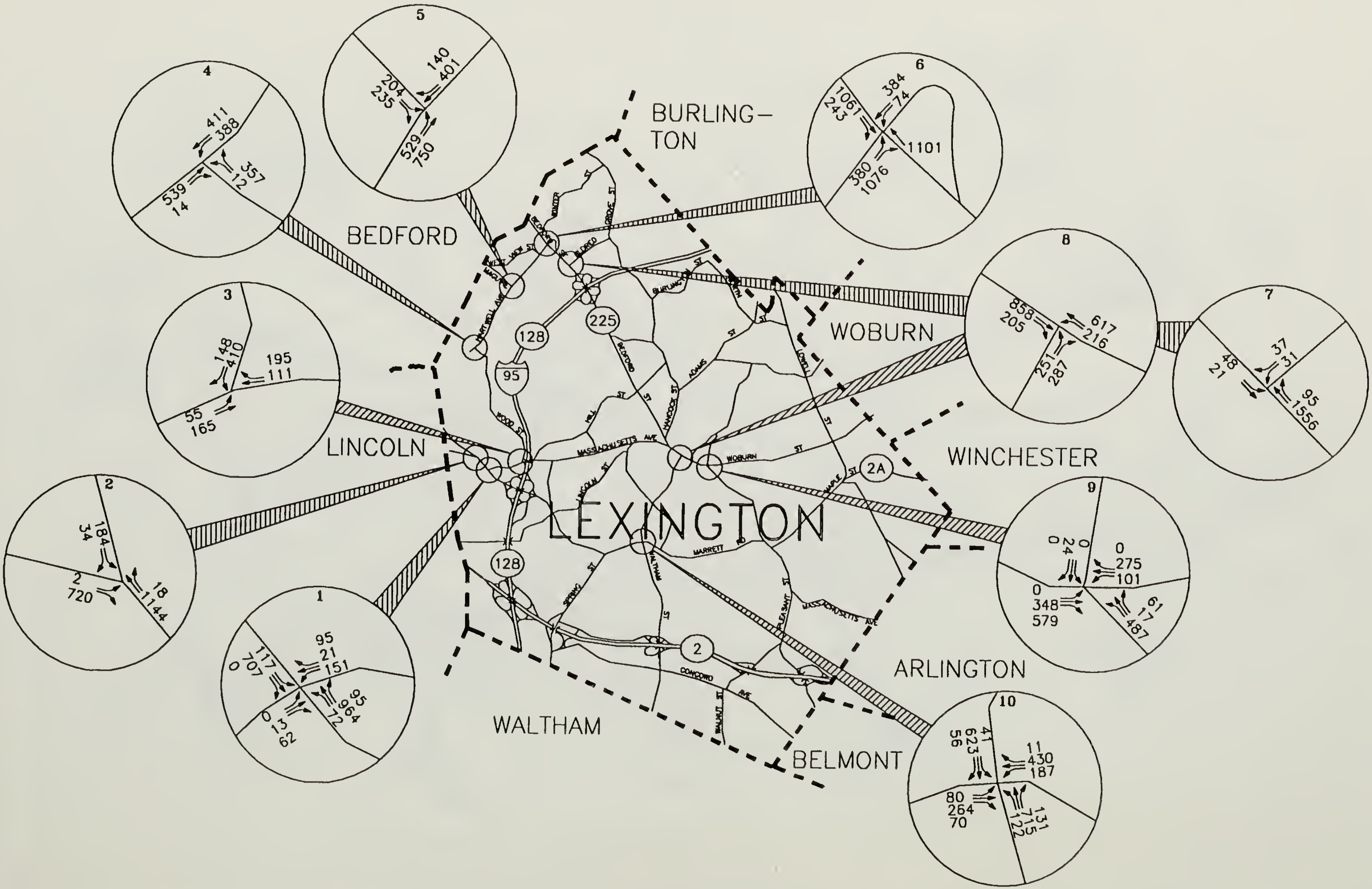


FIGURE 3-9
1995 AM Peak Hour No-Build Traffic Volumes - Lincoln

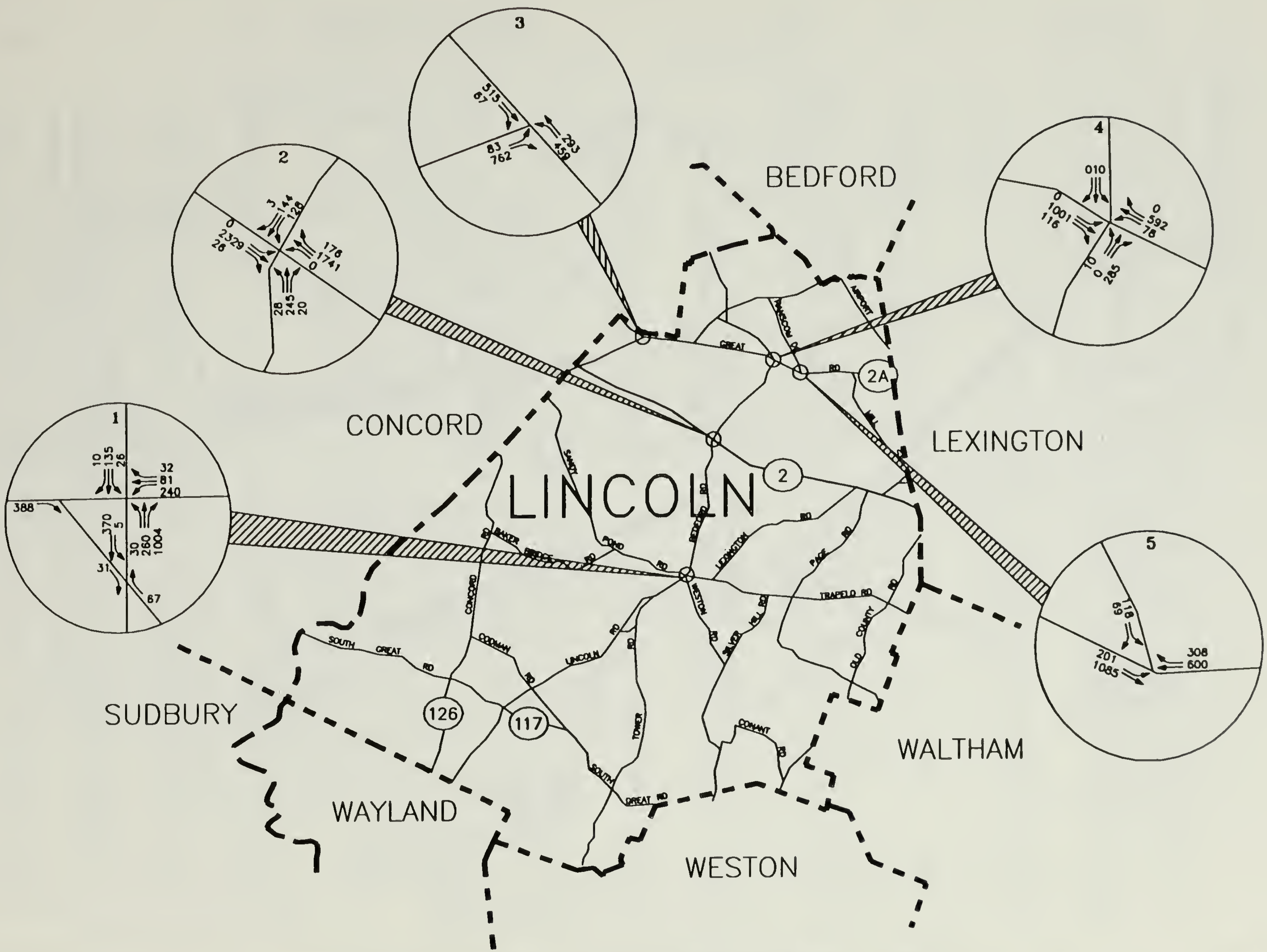
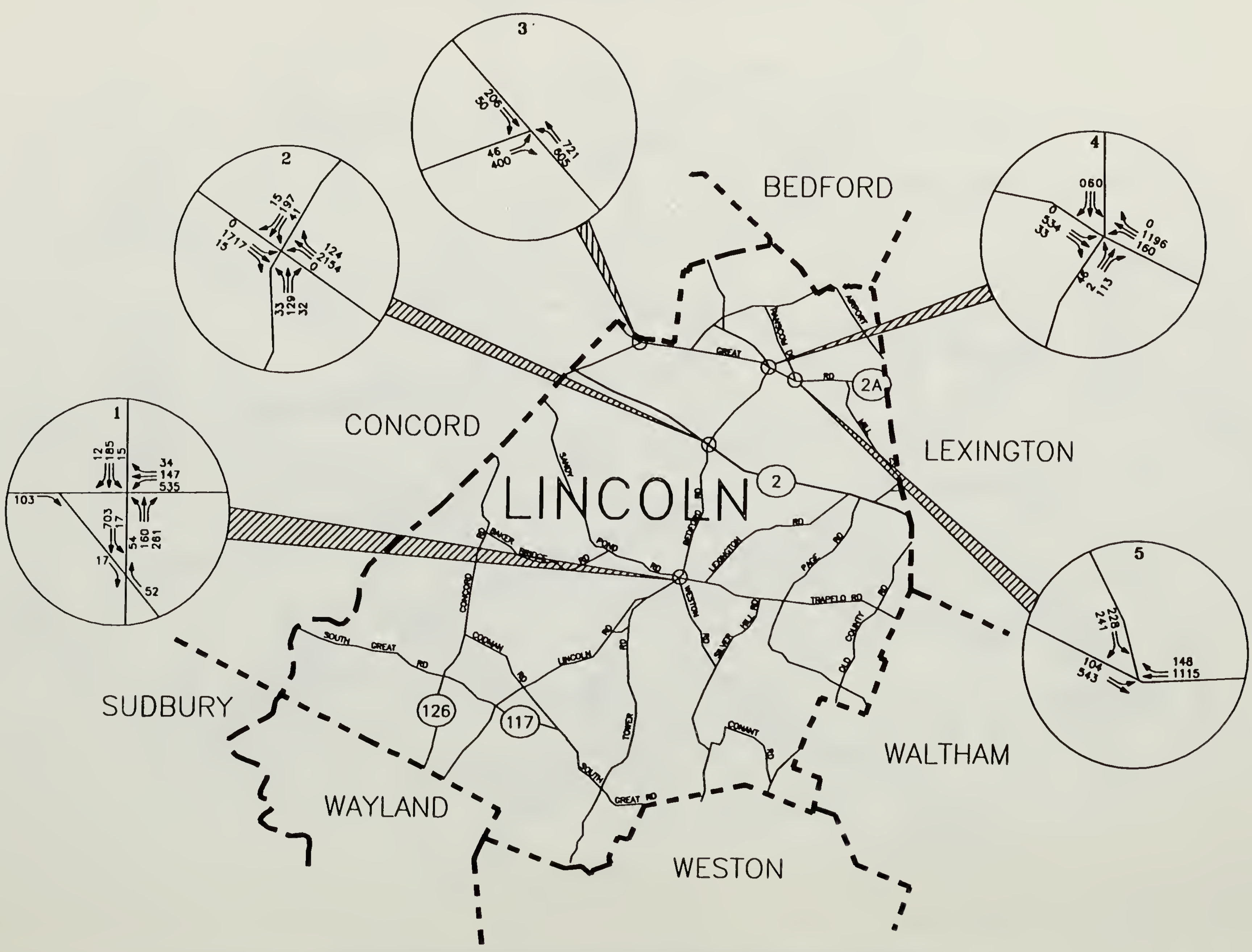


FIGURE 3-10
1995 PM Peak Hour No-Build Traffic Volumes - Lincoln



3.4 RELOCATED EMPLOYEE TRIPS

The relocation of 532 employees to the new on-base MIT Lincoln Laboratory worksite from the currently leased space will result in approximately 234 additional trips into and 13 additional trips out of the Lincoln Laboratory area of HAFB during the AM peak hour. The estimate of 234 new arriving trips results from several factors:

- 55% of the relocated employees will arrive during the AM peak hour of the surrounding roadways (8:00 AM to 9:00 AM).

- The average auto occupancy of trips to the base is 1.25 persons per auto.

During the PM peak hour the relocation of the 532 employees will result in approximately 162 additional departing trips and 16 additional arriving trips. This estimate results from the following factors:

- 38% of the relocated employees will leave during the PM peak hour of the surrounding roadways (5:00 PM to 6:00 PM).

- The average auto occupancy of trips to the base is 1.25 persons per auto.

The source of the auto occupancy figure of 1.25 persons per auto is from the "Component Plan I Transportation Plan" by the Benham Group of Oklahoma, which was commissioned by Hanscom Air Force Base and completed in March 1989. The percentages of employee trips arriving and departing during the peak hours were calculated utilizing knowledge of existing MIT Lincoln Laboratory arrival patterns as documented in the "Traffic Impact Analysis with Addendum for MIT/Lincoln Laboratory" by Abend Associates, September 27, 1988, and the actual Air Force Base gate counts from the component plan cited above and knowledge of the number and type of employees working at MIT Lincoln Laboratory.

The travel paths to and from MIT Lincoln Laboratory of these relocated trips were estimated based on the following factors:

- Knowledge of the residence of existing MIT Lincoln Laboratory employees from the Zip Code of residence of employees. (See section 2.2 of this report)

- Existing travel patterns to and from the MIT Lincoln Laboratory facilities as documented through turning movement counts from a variety of sources.

- Site Plan for the new Lincoln Laboratory facility and parking structure.

- Characteristics of the surrounding roadway network as documented through field work and modelled through the CTPS travel demand model of the study area.

Based on the above factors, the relocated trips arriving at the MIT Lincoln Laboratory during the AM peak hour will be distributed in the following manner. Approximately 35% of the trips will enter MIT Lincoln Laboratory via Hartwell Avenue. Of the Hartwell Ave. trips, 19% will arrive from the north, and 25% will come from the south. Access via Airport Road will account for 27% of the arriving trips with 4% coming from the west and 23% from the east. Wood Street from the south will be the likely path for approximately 23% of the relocated employee trips in the AM peak hour. Of the remaining trips, 12% will arrive via Hanscom Drive from the west and 4% will utilize Virginia Road. The PM exiting trips will leave HAFB following a similar distribution of paths as in the AM.

Figures 3-11 through 3-16 represent the Hanscom Air Force Base area roadway network and include key surrounding intersections. 1995 No-Build (before the relocation), Development Related Trips, and 1995 Build (after the relocation) traffic volumes are detailed.

FIGURE 3-11
HAFB Area 1995 AM Peak Hour No-Build Traffic Volumes

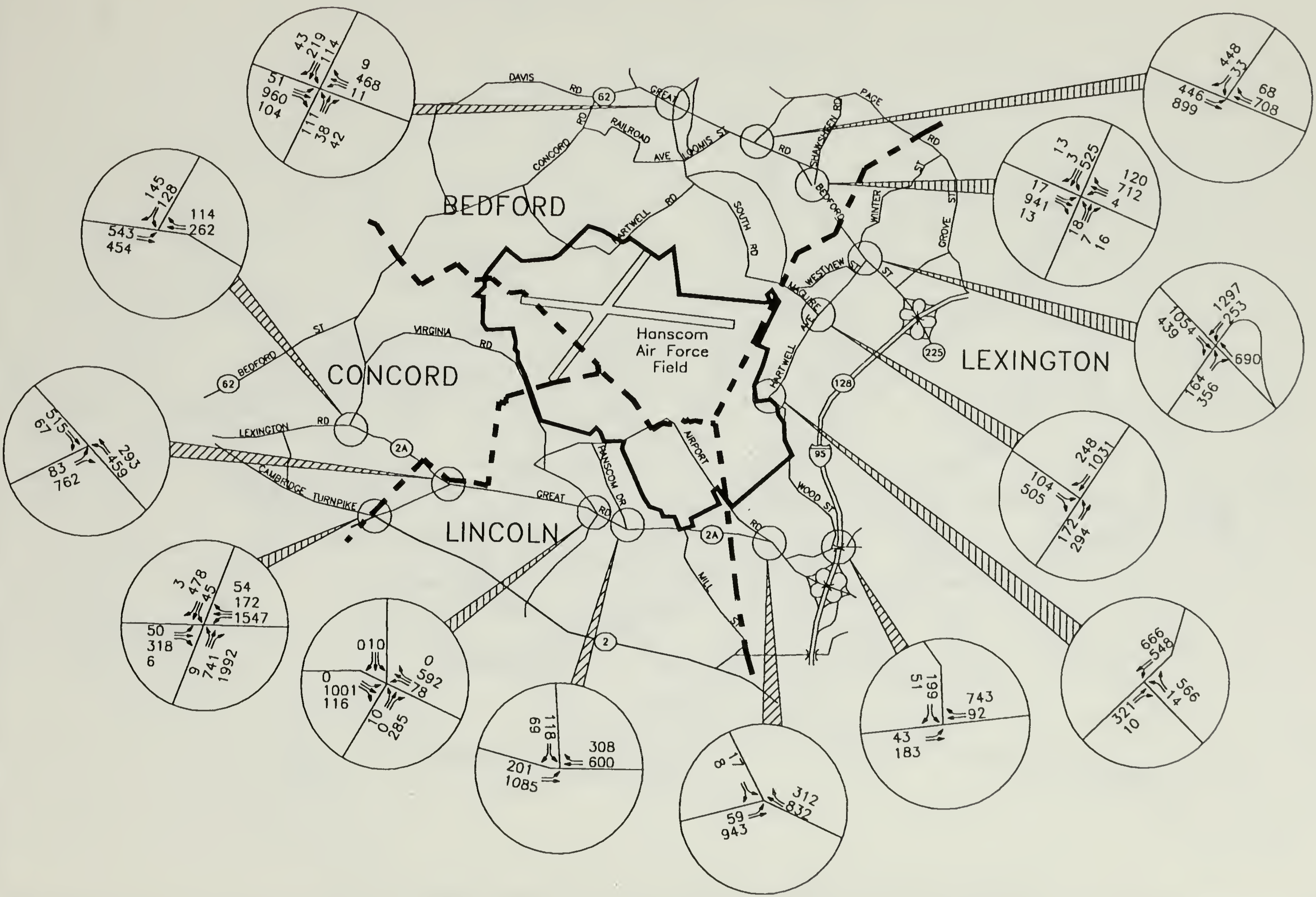


FIGURE 3-12
HAFB Area 1995 AM Peak Hour Development Related Traffic Volumes

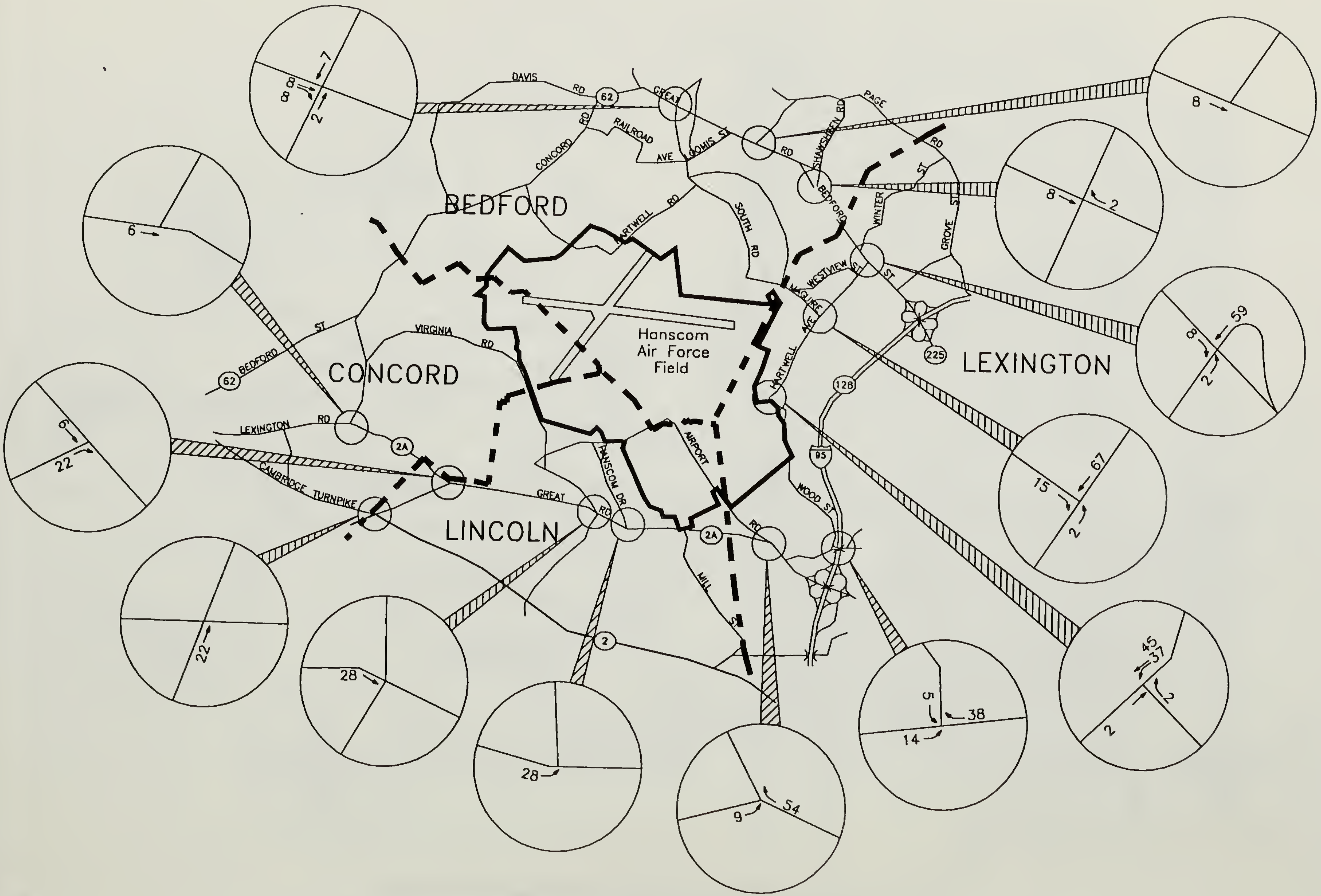


FIGURE 3-13
HAFB Area 1995 AM Peak Hour Build Traffic Volumes

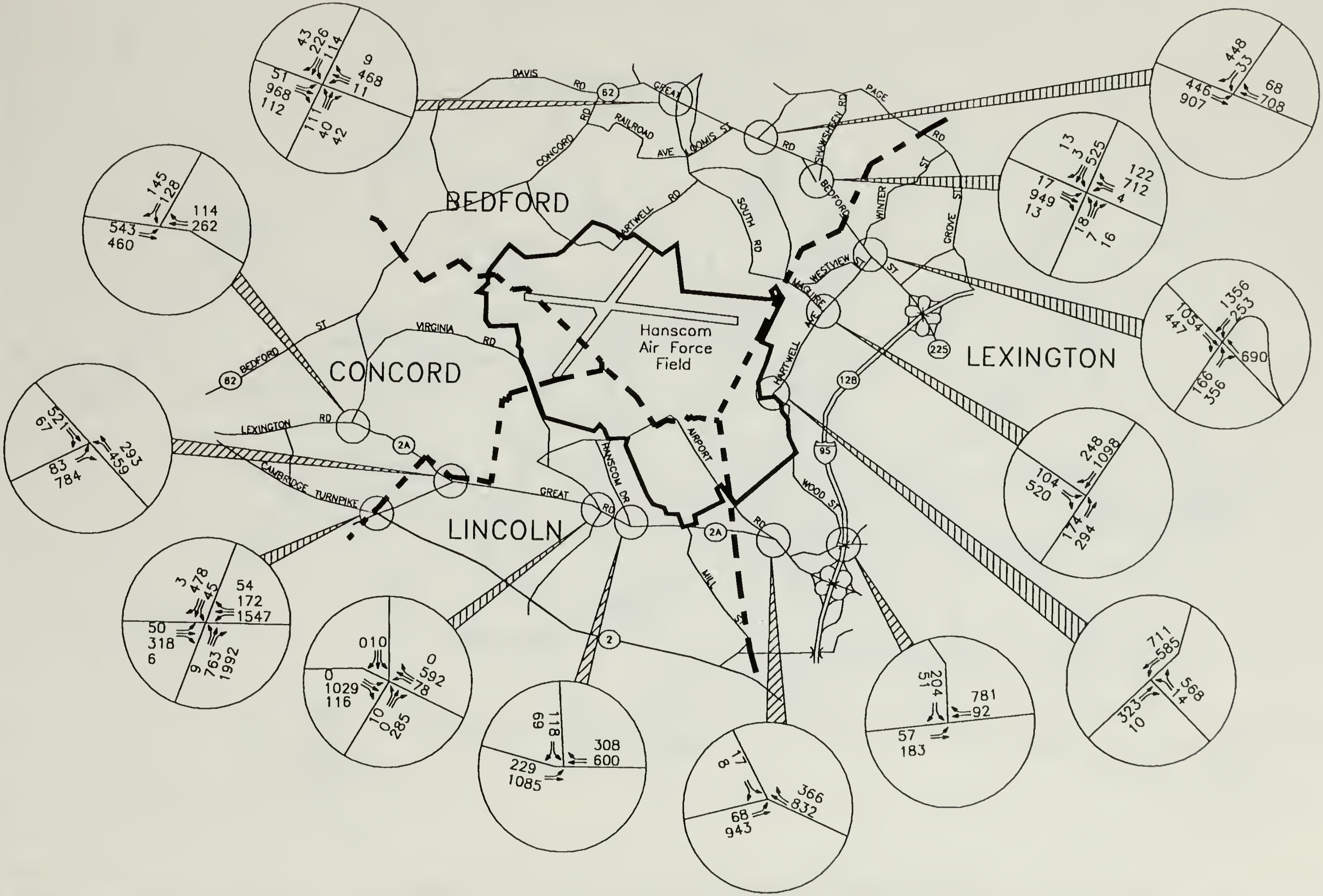


FIGURE 3-14
HAFB Area 1995 PM Peak Hour No-Build Traffic Volumes

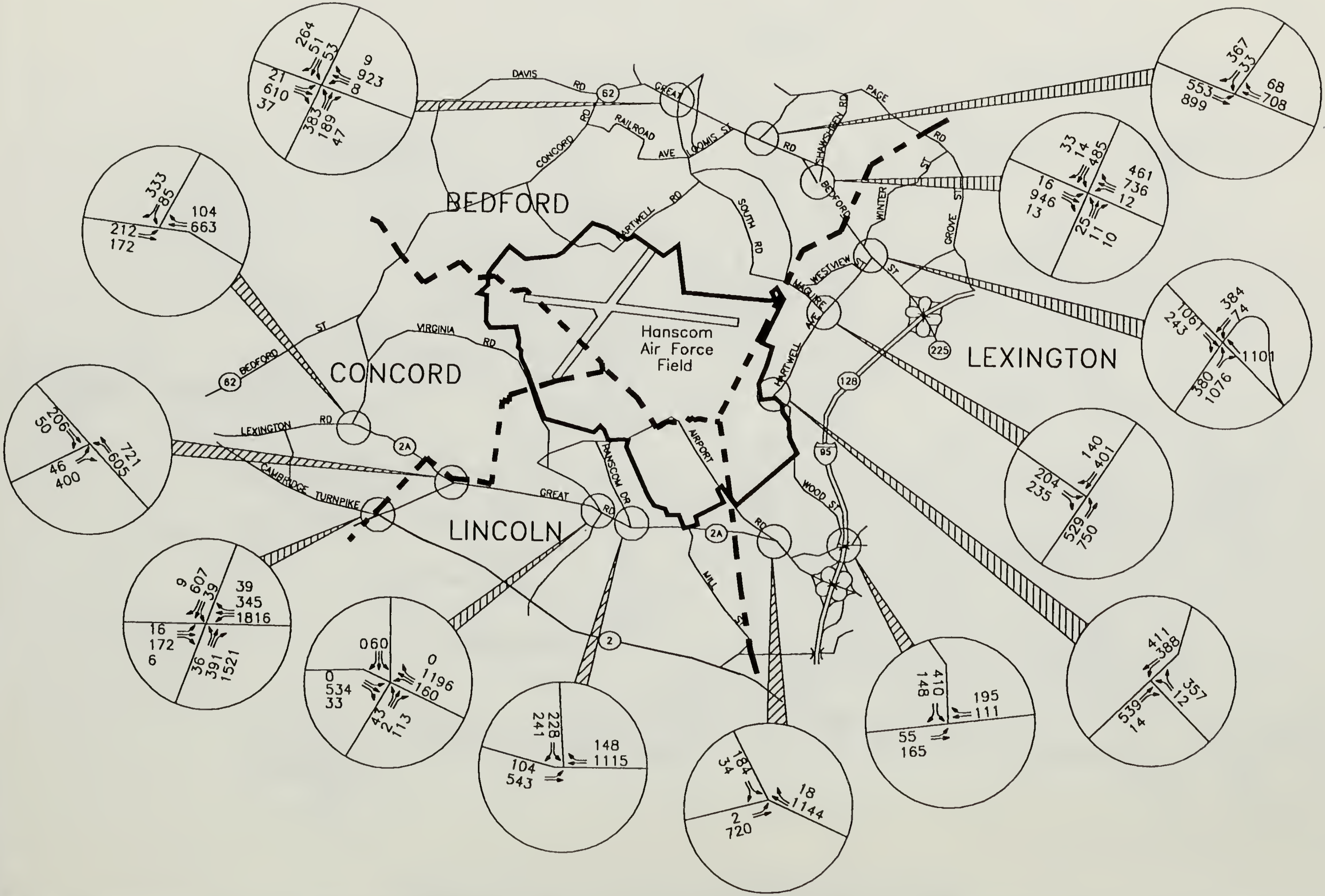


FIGURE 3-15
HAFB Area 1995 PM Peak Hour Development Related Traffic Volumes

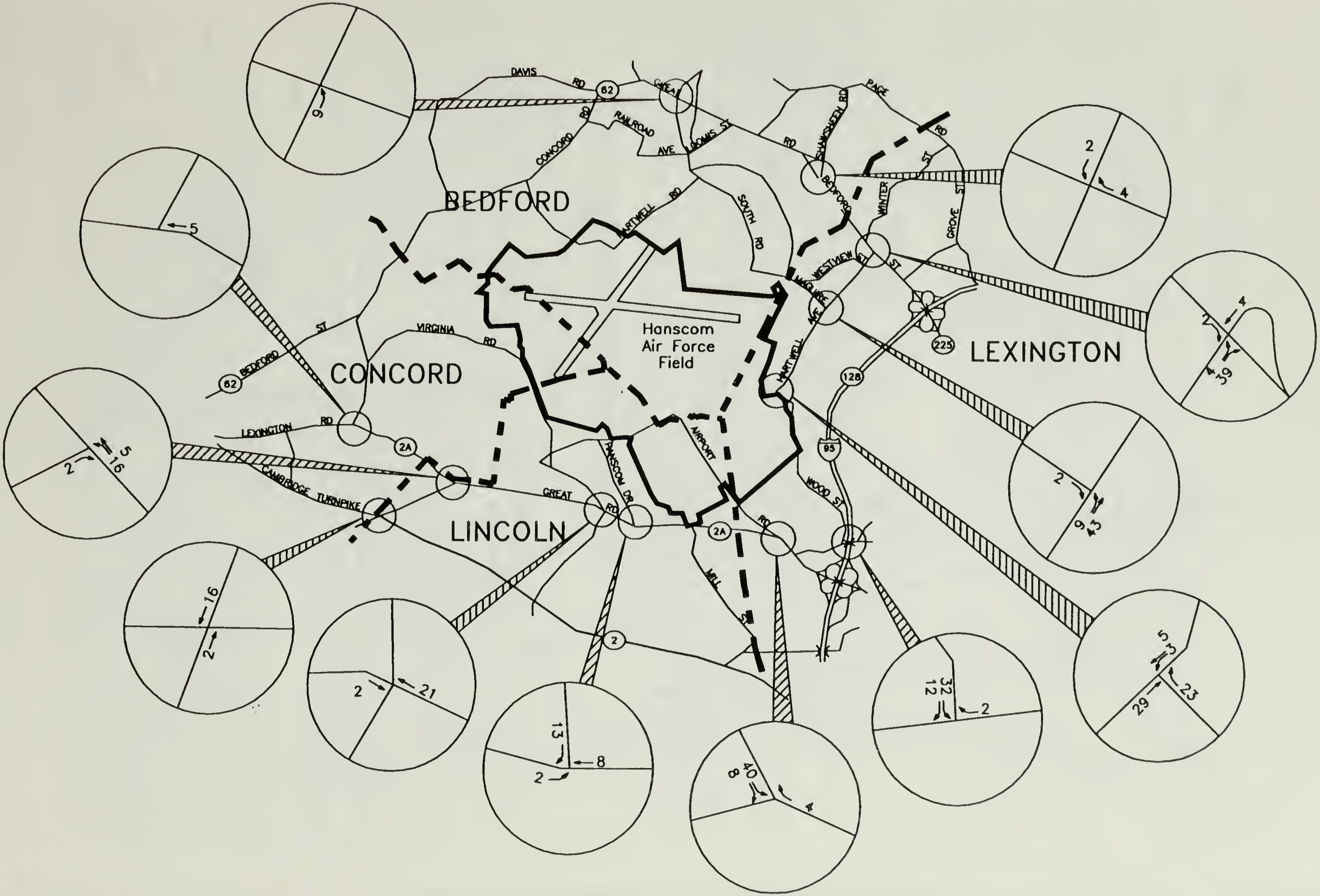
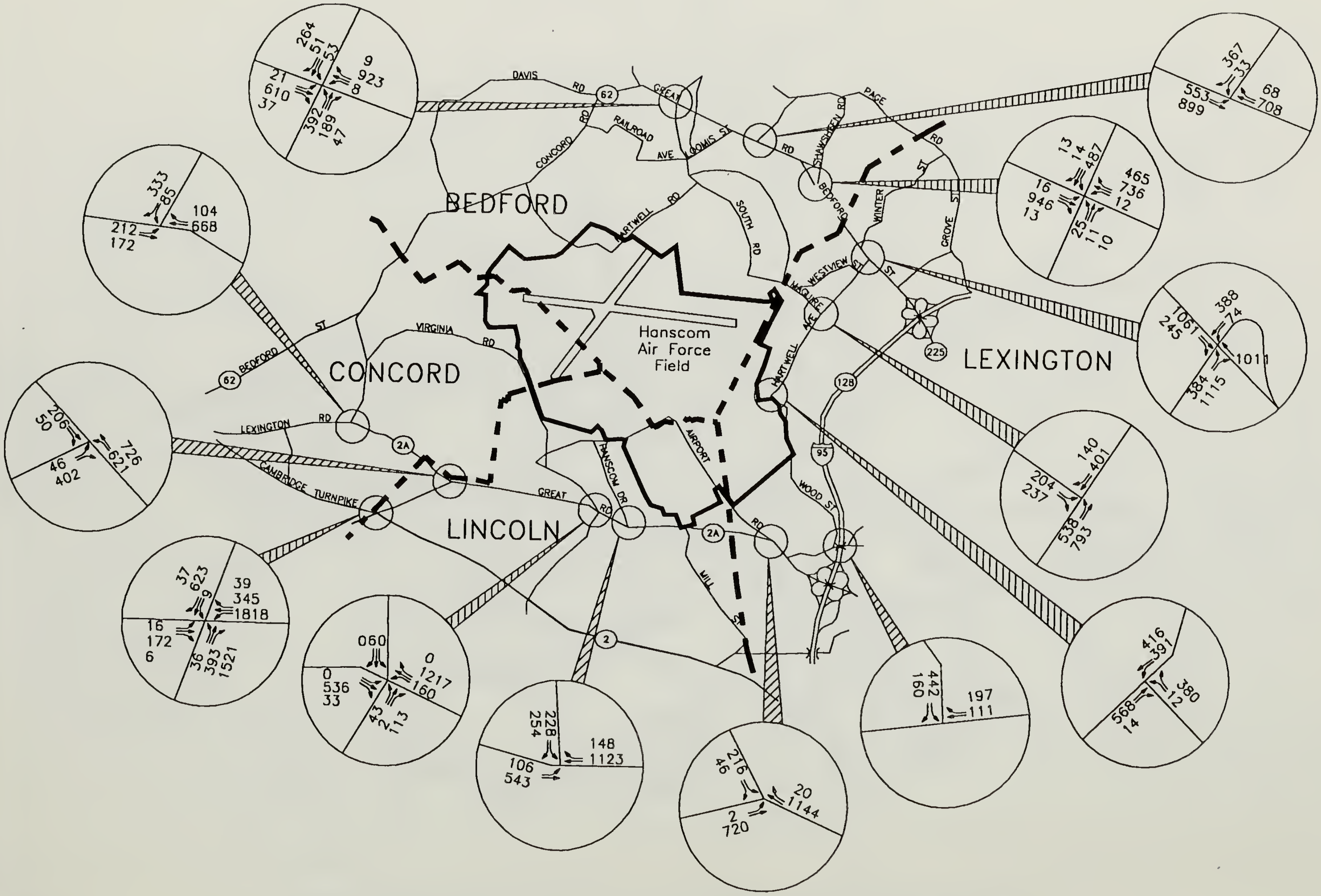


FIGURE 3-16
HAFB Area 1995 PM Peak Hour Build Traffic Volumes



3.5 <u>LEVEL-OF-SERVICE ANALYSIS</u>

As explained in Section 2.4, the 1990 traffic volumes, although still high, were significantly reduced over those of 1989. The positive effects of this reduction to the 1990 intersection level of service will carry on into 1995. The additional background traffic growth from 1990 to 1995 and the growth attributable to the relocation will therefore utilize some or all of the freed up capacity. The impacts of this growth will therefore not be as substantial as it might have been had the growth been added to the 1989 traffic volumes. Also, because of the depressed economy, the background growth itself will not be significant, further enhancing the effect of the reduced 1990 traffic volumes.

Generally speaking, small increases in delay at the signalized intersections will occur, due to both background and relocation related traffic growth. As for the unsignalized intersections, some decreases in LOS are observed for specific approachs due to background traffic growth. In addition, background traffic growth causes decreases in reserve capacity which are not significant enough to cause a decline in a level of service level. The relocation impacts to unsignalized intersections do not cause any LOS decreases but do cause some turning movements to experience decreases in reserve capacity. The specifics of these general observations can be deduced from the results of the analysis presented below.

3.5.1 <u>Signalized Intersections</u> (Table 3-2)

Route 4/225 at Hartwell Avenue

<u>Background Effects</u>: In the 1995 AM peak hour, the overall intersection LOS will be D, the same as in 1990. However, the stopped delay will increase somewhat, from 26 to 31 seconds. This increase in delay will result from an increase of vehicles through the intersection, primarily in the eastbound and southbound direction. Minor increases in delay, will occur on the Hartwell Av. approaches during the PM peak hour, a result of slight volume increases. The overall intersection delay in the PM peak hour will increase from 27 to 28 seconds with the approach and overall LOS of the intersection remaining at D, the 1990 level.

<u>Relocation Effects</u>: In the AM peak hour, all approaches will experience increases in delay between 2 and 8 seconds. The overall intersection delay will increase from 31 to 36 seconds, attributed to the addition of the relocation traffic from the east and the south. However, with the exception of the jughandle approach where the LOS drops from D to E, all other approaches and that of the overall intersection will remain unaffected by the relocation. In the PM peak hour, no change in the approach or overall intersection LOS is expected. However, delay will

increase slightly, from 28 to 30 seconds for the overall intersection.

Route 4/225 at Shawsheen Road/Pine Street

Background Effects: By 1995, background growth will not cause the approaches of the intersection to drop in LOS in the AM peak hour. Only a slight increase in delay will be observed in the westbound and eastbound direction caused by the traffic volume increase in through movements. The intersection will perform at LOS F, due primarily to the poor performance of the Shawsheen Rd. approach. In the PM peak hour, the Rt. 4/225 eastbound approach will drop to LOS D with 29 seconds in delay. The drop will be caused by increased volume in the eastbound through movement. Some increase in the westbound through movement will also result in longer delays and queues in that approach. The overall intersection LOS will remain at F.

Relocation Effects: In the AM peak hour, the relocation has no significant effect on this intersection. The approach and overall LOS will not change and the stopped delay will increase only by fractions of a second. In the PM peak hour, the delay on Shawsheen Rd. will increase somewhat due to a small increase in the number of left turns to Rt. 4/225 eastbound. Delay increases at other approaches will be insignificant causing no change in the LOS. The overall LOS, F, will remain the same with an overall delay increase of 3 seconds. The relocation will have no other significant effects at this location.

Route 4/225 at South Road/Hancock Street

Background Effects: In the AM peak hour, the background growth will not cause delay increases with the exception of Rt. 4/225 eastbound. This approach, at LOS F in 1990 and 1995, will experience an increase in delay due to a through volume increase. In the PM peak hour, background through traffic growth will cause the Rt. 4/225 eastbound approach to drop from B to C and the Rt. 4/225 westbound approach to drop from D to F. The other approaches will not be affected. However, the overall LOS will drop from D to E with a delay increase from 34 to 50 seconds.

Relocation Effects: Small increases of through and right turn volume at the Rt. 4/225 eastbound approach will add to the delays at this approach. No significant changes in delay or LOS will be observed at the rest of the approaches. The overall intersection LOS will remain at F with a small overall delay increase. In the PM peak hour no decrease in LOS will occur with the exception of the South Rd. approach which will experience a delay increase from 61 to 69 seconds. The delay at the other approaches will not be affected.

Route 2A at Massachusetts Avenue

A signalization upgrade and geometric improvement for this intersection are currently in the design stage. The future year level of service analysis presented here assumes that these improvements are in place. There is no correlation between unsignalized LOS grades and signalized LOS grades; the two should not be compared. Analysis of the signal upgrade and geometric improvement plan under existing 1990 and 1995 conditions before the relocation indicates that the improvement will provide sufficient capacity to satisfy existing and forecast demand. The lowest LOS will be at the Massachusetts Avenue approach which will perform at E during both peak hours. However, the improvement will provide increased safety at this location.

Relocation Effects: Analysis indicates that the Rt. 2A westbound approach in the AM and the Rt. 2A eastbound approach in the PM will sustain minor additional delays due to increased westbound and eastbound through movements, respectively. These changes will result from an increase in the number of vehicles entering the Airport Rd. gate in the AM, and exiting the Airport Rd. gate in the PM. The relocation will have no other significant effects on this intersection.

TABLE 3-2

1995 Before and After Relocation Level Of Service Signalized Intersections

Location	AM BEFORE LOS	AM BEFORE DEL	AM AFTER LOS	AM AFTER DEL	PM BEFORE LOS	PM BEFORE DEL	PM AFTER LOS	PM AFTER DEL
Route 4/225 @ Hartwell Av.								
- Hartwell Av.	D	30	D	33	D	29	D	31
- Jughandle	D	36	E	42	D	29	D	31
- Rt. 4/225 WB	C	21	C	23	D	35	D	39
- Rt. 4/225 EB	D	31	D	36	C	20	C	22
Route 4/225 @ Shawsheen Road/ Pine Street								
- Shawsheen Rd.	F	*	F	*	F	*	F	*
- Pine St.	B	14	B	14	B	14	B	14
- Rt. 4/225 WB	B	7	B	7	F	*	F	*
- Rt. 4.225 EB	B	8	B	9	D	29	D	30
Route 4/225 @ South Road/ Hancock Street								
- South Rd.	C	16	C	16	F	61	F	69
- Hancock St.	D	26	D	27	D	37	D	37
- Rt. 4/225 WB	B	9	B	9	F	74	F	74
- Rt. 4/225 EB	F	*	F	*	C	15	C	15
Route 2A @ Massachusetts Av.								
- Mass. Av.	E	49	E	59	E	46	E	46
- Minuteman Dr.	B	10	B	11	A	4	A	4
- Rt. 2A WB	B	15	C	18	C	17	C	19
- Rt. 2A EB	B	11	B	12	C	15	C	16

* Expected average stopped delay per vehicle exceeds 120 seconds

3.5.2 Unsignalized Intersections (Table 3-3)

Route 2A at Bedford Road/Virginia Road

Background Effects: In the AM peak hour, the Bedford Rd. approach will drop in LOS from E to F. The drop will be caused by the traffic increase in the right turns from Bedford into Rt. 2A eastbound. All other movements of this intersection during both the AM and the PM peak periods will remain at the 1990 levels with small drops in their reserve capacity. However, the reserve capacity of the Rt. 2A westbound left turn into Bedford

Rd., a very important movement for the operation of this intersection, will decrease by only 3 vehicles.

Relocation Effects: No LOS drops will occur in the AM or PM peak period. The reserve capacity of the critical movements will decrease slightly.

Route 2A at Hanscom Drive

NOTE: Analysis of the PM peak hour under police officer control is provided in Section 3.5.3.

Background Effects: In the AM peak period, the LOS will remain at the 1990 levels with some decrease in reserve capacity.

Relocation Effects: In the AM peak hour, the Rt. 2A left turn will decline from LOS A to LOS B as the result of a decrease of 92 vehicles in reserve capacity.

Route 2A at Airport Road

NOTE: Analysis of the PM peak hour under police officer control is provided in Section 3.5.3.

Background Effects: In the AM peak hour, the left turn from Rt. 2A will drop from LOS B to LOS C, due to a 51 vehicle decrease in reserve capacity.

Relocation Effects: In the AM peak period, the relocation will not affect the Airport Rd. approach or the Rt. 2A eastbound left turn in terms of LOS drop. However, the reserve capacity of the latter movement will decrease by 33 vehicles.

Route 2A at Massachusetts Avenue

See the analysis presented in Section 3.5.1, above.

Hartwell Avenue at Wood Street

Background Effects: In the AM peak hour, the LOS of the right turn from Wood St. will drop from A to B with a decrease in reserve capacity by 91 vehicles. The LOS of the left turn from Hartwell Av. and Wood St. will remain at F, for both peak hours. The reserve capacity will decrease somewhat with the exception of the Hartwell Av. left turn into Wood St. which will lose 103 vehicles of reserve capacity, a significant decrease.

Relocation Effects: The relocation will not cause LOS drops at this location during either of the peak hours. However, the reserve capacity will decrease by 65 vehicles in the AM at the Hartwell Av. left turn and by 43 vehicles in the PM peak hour at the Wood St. right turn.

Hartwell Avenue at Maguire Road

NOTE: Analysis of the PM peak hour under police officer control is provided in Section 3.5.3.

Background Effects: In the AM peak hour, the right turn from Maguire Rd. will experience a drop in LOS from E to F. Other than this change, background growth will have no LOS impact or cause significant loss of reserve capacity at this location, during both peak hours.

Relocation Effects: Analysis showed no LOS or significant reserve capacity impacts at this location.

Route 4/225 at Eldred Street

Left turns out of Eldred St. are currently prohibited during the AM and PM peak periods but vehicles were observed entering and exiting this location.

Background Effects: Background growth will not cause any significant changes at this intersection.

Relocation Effects: The relocation will not cause any significant changes at this intersection.

Route 4/225 at Brooksbie Road (Route 62)

Background Effects: In the AM peak hour, the left turn from Rt. 4/225 into Brooksbie Rd. will suffer a decrease of 123 in reserve capacity, and a change in LOS from C to D. In the PM peak hour the same movement will suffer a loss of 70 in reserve capacity and a drop in LOS from E to F.

Relocation Effects: The relocation will have no effect in terms of LOS drop or reserve capacity loss during either peak hour.

TABLE 3-3

1995 Before and After Relocation Level of Service
Unsignalized Intersections

	AM				PM			
	BEFORE		AFTER		BEFORE		AFTER	
Location	LOS	RC	LOS	RC	LOS	RC	LOS	RC
Route 2A @ Bedford Road/ Virginia Road								
- Rt. 2A WB LT	C	286	C	266	A	483	A	501
- Virginia Rd.	E	62	E	57	E	37	E	39
- Bedford Rd.	F	-22	F	-40	F	-47	F	-58
Route 2A @ Hanscom Drive								
- Rt. 2A EB LT	A	428	B	392	NA		NA	
- Hanscom Dr. LT	F	-116	F	-120	NA		NA	
- Hanscom Dr. RT	A	724	A	721	NA		NA	
Route 2A @ Airport Road								
- Rt. 2A EB LT	C	298	C	265	NA		NA	
- Airport Rd.	E	16	E	12	NA		NA	
Hartwell Av. @ Wood Street								
- Hartwell Av. WB LT	F	-139	F	-204	F	-125	F	-152
- Wood St. LT	F	-14	F	-14	F	-14	F	-14
- Wood St. RT	B	388	B	385	B	394	B	351
Hartwell Av. @ Maguire Road								
- Hartwell Av. EB LT	E	33	E	12	NA		NA	
- Maguire Rd. LT	F	-124	F	-129	NA		NA	
- Maguire Rd. RT	F	-34	F	-76	NA		NA	
Route 4/225 @ Eldred Street								
- Rt. 4/225 EB LT	E	49	E	44	D	103	D	102
- Eldred St.	F	-50	F	-56	F	-79	F	-79
Route 4/225 @ Brooksbie Road (Route 62)								
- Rt 4/225 EB LT	D	123	D	123	F	-21	F	-21
- Brooksbie Rd.	F	-446	F	-447	F	-439	F	-439

3.5.3 <u>Police Officer Control</u> (Table 3-4)

Police officer intersection control was simulated through the use of signalized analysis methods. The phasing scheme was determined from field observation, (with the exception of Hartwell and Maguire which was not observed, but analyzed as if it were an optimized signal). At the Hanscom Dr. intersection, it was observed that the controlling officer clears most (if not all) of the queues for the critical moves (the left turn from Rt.2A and all moves from Hanscom Dr.) at the expense of lengthy queues on the Rt. 2A mainline. (It was assumed that a similar method is used at Airport Rd.) This analysis was done with the observed phasing but assumed that the officer does not necessarily clear the Hanscom Dr. queues. Instead, he attends to the safe exit of motorists from the Drive without neglecting the queues formed at the mainline. Therefore, the results of the analysis reflect how the intersection would operate with an officer who acts like a vehicle actuated traffic signal.

Route 2A at Hanscom Drive

In keeping with the above description of this analysis process, the LOS for all three approaches remained the same for all three scenarios, E for Hanscom Dr. and E for the Rt. 2A mainline approaches. The longest delay, approximately 45 seconds, would be experienced by the Hanscom Dr. approach motorists. The shorter delay, between 15 and 20 seconds, would be experienced by the mainline motorists. This analysis also indicates that the relocation will not cause significant increases in delay in delay at this intersection.

Route 2A at Airport Road

Analysis showed that the Airport Rd. approach is at LOS F with no change expected by 1995. The Rt. 2A westbound and eastbound approaches are at LOS D and A respectively.eastbound approach will drop to LOS F by 1993. The relocation will increase the Airport Rd. delay to 103 seconds. The Rt. 2A westbound approach will also suffer increased delay and a drop of LOS, from D to E.

Hartwell Avenue at Maguire Road

As with the previous two intersections, the level of service analysis completed for this intersection assumes the presence of a traffic control officer who performs as a vehicle actuated traffic signal, therefore reflecting the best possible conditions at this intersection, minimizing delay for all approaches. In 1990 the Maguire Road approach is at LOS E, while the Hartwell Ave. eastbound approach is at LOS C and the westbound direction is at LOS D. The overall intersection LOS in 1990 is C. In 1995 a slight increase in overall intersection delay makes the overall LOS drop from C to D. Slight increases in delay occur at each of the approaches although there are no changes in LOS levels. The

impacts of the relocation are minimal with only slight increases in delay for each of the approaches and therefore overall delay. There are no LOS changes between build and no-build conditions.

TABLE 3-4

1990 Existing Conditions and
1995 Before and After Relocation
PM Peak Hour Level of Service
Police Officer Control

	1990 PM Peak Hour		1995 PM Peak Hour			
			BEFORE		AFTER	
Location	LOS	DEL	LOS	DEL	LOS	DEL
Route 2A @ Hanscom Drive						
- Hanscom Dr.	E	45	E	42	E	44
- Rt. 2A WB	C	19	C	18	C	18
- Rt. 2A EB	C	16	C	15	C	16
Route 2A @ Airport Road						
- Airport Rd.	F	90	F	88	F	103
- Rt. 2A WB	D	33	D	33	E	50
- Rt. 2A EB	A	3	A	4	B	5
Hartwell Ave. @ Maguire Road						
- Hartwell Av. EB	C	18	C	21	C	23
- Hartwell Av. WB	D	29	D	36	D	38
- Maguire Rd.	E	40	E	43	E	46

4 CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

1990 Traffic Volumes

In general, 1990 observed traffic volumes reflect reduced travel in the study area, when compared to 1988 and 1989 traffic volumes. This trend can be attributed primarily to the downturn in the economy. Some travel paths were experiencing severe congestion in 1988 and 1989 which caused significant diversions throughout the study area roadway network. Due to decreases in traffic volumes, these paths are experiencing increases in capacity, therefore decreasing the need for travel diversions. Analysis of 1990 conditions reveal some improvement in travel conditions in the study area over previous analyses of 1988 and 1989 conditions.

1995 Forecast Traffic Volumes

Overall traffic volumes throughout the study area are forecast to grow by three percent between 1990 and 1995. Because of the improved 1990 conditions, and the small level of growth forecast for the study area, 1995 conditions are marginally acceptable, with some isolated locations experiencing unacceptable levels of delay.

MIT Lincoln Laboratory Relocated Employee Trips and Impacts

The relocation of 532 employees to the new MIT Lincoln Laboratory facility will result in an additional 234 trips arriving and 13 trips leaving the MIT facility during the AM Peak Hour. See Figure 3-12 for a diagramatical depiction of the travel paths of the additional trips. Of these additional trips, 82 of them arrive via Hartwell Avenue, 15 of them utilizing South and Maguire, and 67 of them coming from Route 4/225. Of the new trips entering on Hartwell Avenue, 37 turn left to Wood Street south and 45 go straight on Hartwell into the base. Wood street from the south is the likely arrival path for 52 of the additional AM peak hour arrivals. 63 new trips arrive via Airport Rd., 54 from the east and 9 from the west. 28 new trips arrive via Hanscom Drive from the west.

The additional AM arriving trips account for the following changes in intersection level of service.

- At the jughandle approach of the intersection of Rt. 4/225 at Hartwell Av., the LOS will drop from D to E with a delay increase from 36 to 42 seconds;

- At the Rt. 2A westbound approach of the intersection of Rt. 2A at Massachusetts Av., LOS will drop from B to C with a delay increase of 3 seconds;

- At the Rt. 2A eastbound left turn movement of the intersection of Rt. 2A at Hanscom Dr., LOS will drop from A to B with a loss in reserve capacity of 36 vehicles.

The rest of the movements at these and the remaining intersections will not experience decreases in LOS. However, they will be subject to delay increases or reserve capacity losses of various magnitudes, depending on their relative location with regard to the paths of the relocated trips. Reserve capacity losses range between 0 to 65 vehicles and delay increases range between 0 and 17 seconds. Movements with reserve capacity losses over 10 vehicles and delay increases over 10 seconds include:

- The left turn at the Rt. 2A westbound approach and the Bedford Rd. approach of the intersection Rt. 2A at Virginia Rd. and Bedford Rd.

- The Rt. 2A eastbound left turns at Rt. 2A and Hanscom Dr and at Rt. 2A and Airport Rd.

- The Hartwell Av. left turn movement into Wood St.

- The Hartwell Av. left turn movement into Maguire Rd. and the Maguire Rd. right turn movement.

- The Rt. 4/225 eastbound approach at the intersection of Rt.4/225 at South Rd. and Hancock St.

In the PM Peak Hour, the relocation accounts for an additional 162 trips leaving and 16 trips entering the MIT Lincoln Laboratory facility. Of the new departing trips, 52 exit via Hartwell Avenue, 23 turning right from Wood St. on to Hartwell and 29 exiting straight on Hartwell from the gate. 9 of these Hartwell Ave. exiting trips turn left at Maguire and 43 of them continue straight on Hartwell to 4/225. Airport Rd. carries 48 of the new departures, with 8 new trips exiting west and 40 exiting east. 13 additional trips exit via Hanscom Dr. turning right to go west. Wood St. south is the likely exit path for 44 of the new trips.

The additional PM arriving trips account for the following changes in intersection level of service.

- At the intersection Rt. 2A at Airport Rd., the LOS at the Rt. 2A eastbound and westbound approaches declines from A to B and from D to E, respectively.

However, a number of movements at other intersections analyzed in this study will experience loss of reserve capacity between 0 and 43 seconds or delay increases between 0 and 17 seconds without degradation in LOS. Those movements or approaches with reserve capacity loss greater than 10 vehicles and delay increases more than 10 seconds include:

- At Rt. 2A at Virginia Rd. and Bedford Rd., the Bedford Rd. approach.

- At Hartwell Av. and Wood St., the Hartwell Av. left turn into Wood St. and the Wood St. right turn.

- At Rt. 2A and Airport Rd., the Airport Rd. approach.

These findings are consistent with the LOS sensitivity of the travel paths to be used by the relocated trips. Many locations along these paths are already known for their capacity deficiency not only because of future background growth but also because of the existing traffic volumes.

In summary, the highest losses in reserve capacity caused by the relocation will be at the Hartwell Av. left turn movement in the AM (65 vehicles), the Wood St. right turn movement in the PM (43 vehicles) and the Maguire Rd. right turn in the AM (42 vehicles), the Rt. 2A left turn into Hanscom Dr. (36 vehicles) in the AM and the Rt. 2A left turn into Airport Rd. (33 vehicles) in the AM peak hour. At the rest of the intersections the delay increases and reserve capacity losses diminish with distance from the the four HAFB gates.

Relocation Impacts at Hartwell Avenue and Wood Street

This location meets the peak hour volume traffic signal warrant during both peak hours in 1990. Even when the existing MIT traffic is excluded from the analysis, this intersection meets the peak hour traffic signal warrant in the 1990 AM and marginally in the 1990 PM peak hour .

This location will benefit greatly from a traffic signal, since its installation will ensure the orderly and safe processing of all critical moves (the right turn from Wood St. and the left turn from Hartwell Av.) without compromising the LOS and safety of Hartwell Av. through traffic. With a traffic signal the overall LOS at this location will be C or better for 1990 and 1995 before and after the relocation. The recommended

signal design calls for the Hartwell Av. westbound approach to consist of one through and one exclusive left-turn lane. The Wood St. approach should be restriped to include a short exclusive left-turn lane. These geometric changes can be accomplished within the existing pavement width. The signal should have a three-phase cycle, with a leading green for the left and through movements from Hartwell Av.

4.2 RECOMMENDATIONS

On the basis of the discussion in Section 3.4 and the conclusions in Section 4.1, the following is recommended:

Route 2A at Hanscom Drive

Police officer control should continue in the afternoon peak hour. Also, the initiation of an officer's service in the morning peak hour would be beneficial. Additionally, it is recommended that the officer modify the presently practiced control to allow additional time to the Rt. 2A mainline. This measure will be beneficial to the overall performance of the intersection.

Route 2A at Airport Road

Police officer control of this intersection in the PM peak hour should be continued, with a modified control cycle as recommended for the Hanscom Drive intersection.

Hartwell Avenue at Wood Street

The installation of a vehicle actuated traffic signal with the indicated channelization and signal phase design is a necessity at this location for safety and level of service purposes. It is recommended that this signal be installed to provide for the safe processing of the traffic generated by present and relocated MIT Lincoln Laboratory employees in time to coincide with the opening of the new facility.

Hartwell Avenue at Maguire Road

A vehicle actuated signal should be installed at this location and probably coordinated with those at Rt. 4/225 and Wood Street. The Hartwell Av. northbound approach should consist of one exclusive left-turn lane and one through lane. The Maguire Rd. approach should include two left-turn lanes. These geometric changes can be accomplished within the existing pavement width. The signal cycle should have three phases, with a leading green for the left turns from Hartwell Av. Until the signalization is complete, the police officer control in the PM peak should continue.

Hartwell Avenue

Presently, the Wood Street and Maguire Road intersections are included in the preliminary design of Hartwell Avenue undertaken by BSC Associates for the city of Lexington. The consultant intends to propose the signalization of the Wood Street and Maguire Road intersections along with other capacity and safety improvements on Hartwell Avenue. Improvements to the Hartwell Ave. and Route 4/225 intersection have also been proposed as part of an improvement plan for Route 4/225 from Route 128 to Eldred St. While the need for signalization at both Maguire and Wood Street exists currently, an overall plan for improvements to Hartwell Avenue and its intersections should be developed and agreed upon by all involved parties as soon as possible, prior to individual intersection improvements.